HARE (Robt.)

Engravings and descriptions
of the great part of the
apparatus
used in
the Chemical Course
of the University of Pennsylvania

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Isaac C. Hall.

ENGRAVINGS, AND DESCRIPTIONS,

OF A GREAT PART OF THE

APPARATUS

USED IN THE

Chemical Course

OF

THE UNIVERSITY OF PENNSYLVANIA.

WITH

APPROPRIATE THEORETICAL EXPLANATIONS.

BY

ROBERT HARE, M. D.

PROFESSOR OF CHEMISTRY.

PRINTED FOR THE USE OF HIS PUPILS.

IN TWO PARTS.

PART I.

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PREFACE.

After some years experience, I was convinced that the time spent in the lecture-room, might be rendered much more profitable, if students could be previously apprized, as far as possible, of the chain of ideas, or the apparatus and experiments to be subjected to attention at each lecture; especially as a method of refreshing the memory afterwards, might by the same means be afforded.

It was in consequence of this conviction, that the Minutes, of my course of instruction, were printed; and in obedience to the same impressions, I have now prepared a work comprising with few exceptions, engravings and descriptions of such of my chemical and mechanical apparatus and experiments, as are susceptible of being in this way elucidated.

I have not yet been enabled to obtain engravings, of all my electrical and galvanic apparatus.

Of a considerable part of the latter, and of some of the former, copperplate engravings will be found at the end of the Supplement to my Minutes.

In order that the engravings and descriptions, may be in the hands of the Students, in due time, I find it necessary to publish that part first, which comes first in my course. The remainder will appear before my lectures extend to that portion of the experiments, to which it appertains.

A chemical class, in a medical school, is usually constituted of individuals, who differ much with respect to their taste for Chemistry, and in opinion as to the extent to which it may be practicable, or expedient for them to learn it. There is also much disparity in the previous opportunities which they may have enjoyed, of acquiring some knowledge of this science, and of others which are subsidiary to its explanation. Hence, a lecturer may expatiate too much for one portion of his auditors, and yet be too concise for

another portion.—While to the adept he may often be too trite, to the novice he may, as often, appear abstruse.

Some pupils, actuated by a laudable curiosity, under circumstances permitting of its indulgence, may desire an accurate knowledge of the apparatus, by which my experimental illustrations are facilitated.—Other pupils may feel themselves justified, perhaps necessitated, not to occupy their time, with any thing which is not indispensable to graduation. In order, therefore, that I may neither create disgust on the one hand, nor disappointment on the other, I shall occasionally, give details and descriptions, in this work, on which I do not mean to dwell during my lectures; and, concerning which, candidates will not, of course, be questioned at the examination.

There may be an advantage in affording details, too minute for lectures, even to those who may not immediately give them attention; since such subjects may be studied during the time which intervenes between sessions of the school; or during the ample leisure, which usually succeeds the attainment, of a medical degree.

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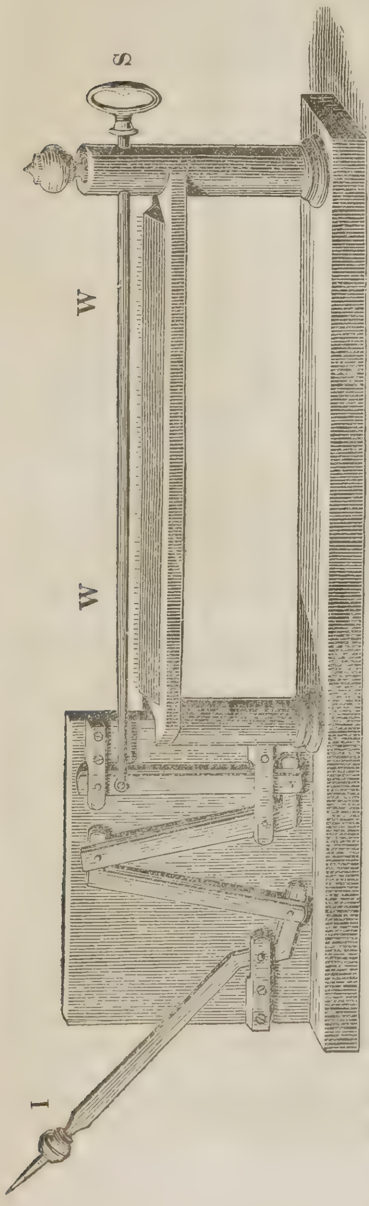
ENGRAVINGS AND DESCRIPTIONS,

&c. &c.

No. 1.—EXPANSION OF SOLIDS.

Influence of Temperature on the length of a Metallic Wire acting on an Index through intervening Levers.



WW represents a wire, beneath which is a spirit lamp, consisting of a long, narrow, hollow, triangular vessel of sheet copper, open along the upper angle, so as to receive and support a strip of thick cotton cloth, or a succession of wicks. By the action of the screw at S, the wire is tightened; and by its influence on the levers, the index I is raised. The spirit lamp is then lighted, and the wire is enveloped with flame. It is of course heated and expanded; and, allowing more liberty to the levers, the index, upheld by them, falls.

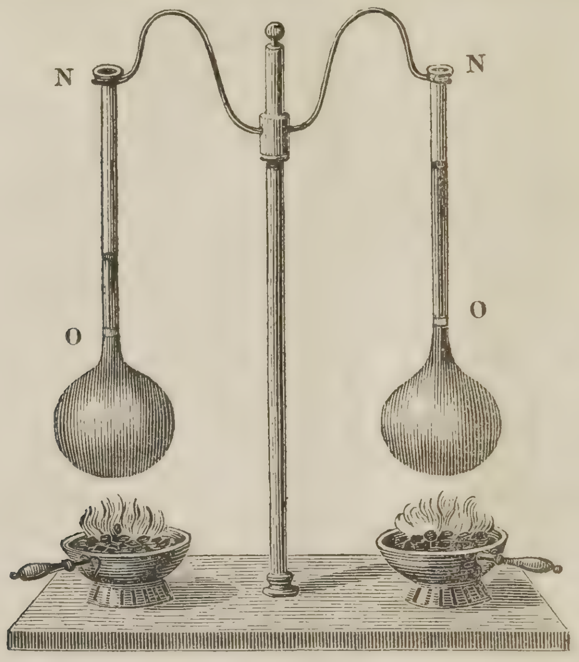
By the action of the screw the wire may be again tightened, and the application of the lamp being continued, will again, by a further expansion, cause the depression of the index; so that the experiment may be repeated several times in succession.

Since this figure was drawn, I have substituted for the alcohol lamp, the more manageable flame of hydrogen gas, emitted from a row of apertures in a pipe supplied by a self-regulating reservoir of hydrogen gas, of which an engraving and description will be given in due time.

If while the index is depressed, by the expansion, ice or cold water be applied to the wire, a contraction immediately follows, so as to raise the index to its original position.

No. 2.—EXPANSION OF LIQUIDS.

Liquids are expanded when their Temperature is raised; and some Liquids, are more expansible than others.



Let two globular glass vessels, as above represented, with long narrow necks, as nearly as possible of the same size and shape, be supplied severally, with water and alcohol, excepting the necks from NN to OO. Under each vessel, place equal quantities of charcoal, burning with a similar degree of intensity. The liquids in both vessels will be expanded, so as to rise into the necks; but the alcohol will rise more than the water.

THEORY OF EXPANSION.

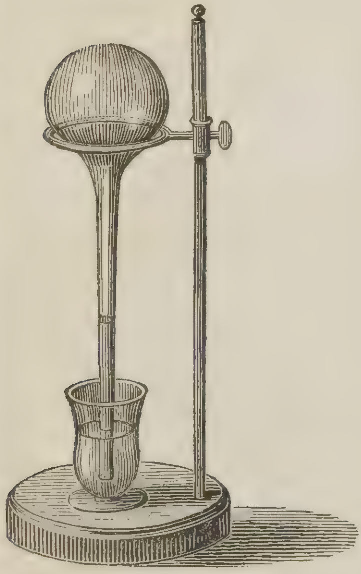
In proportion as the temperature of the external medium is raised, there will be more caloric in and about the spaces occupied by the matter, and consequently within the sphere of its attraction. The more caloric within the sphere of its attraction, the more will combine with it, and in proportion to the caloric thus combined, will be that self-repellant power; which, in proportion to its intensity, causes material particles to exist at a greater or less distance from each other.

It is difficult to account for the greater expansibility of the alcohol. The capacity of this liquid for heat is well known to be

less than that of water,—that is, if it were an object to elevate the temperature of equal portions of water and alcohol, each the same number of degrees, by adding hot sand, less would be required for the alcohol. Of course, as in rising to the same degree of heat, more caloric combines with water, it would seem that it ought to be more expanded. This phenomenon may be associated with a number of others, in which calorific repulsion appears to be paralyzed in a greater or less degree, by some unknown cause, to whose agency the inexplicable phenomena of galvanism, and electro-magnetism, may also be indebted.

No. 3.—EXPANSION OF AIR.

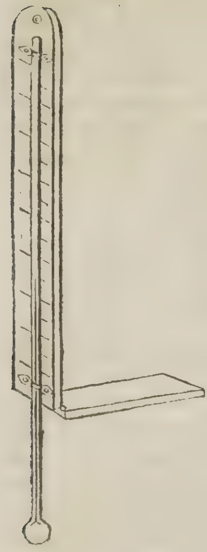
Illustrated by the Air Thermometer of Sanctorio, on a large scale.



The bulb of a mattrass is supported, by a ring and an upright wire, with its neck downwards, so as to have its orifice beneath the surface of the water in a small glass jar. A heated iron being held over the mattrass, the contained air is so much increased in bulk, that the vessel being inadequate to hold it, a partial escape from the orifice through the water ensues. On the removal of the hot iron, as the residual air regains its previous temperature, the portion expelled by the expansion is replaced by the water.

If in this case the quantity of air expelled be so regulated, that when the remaining portion returns to its previous temperature, the liquid rises about half way up the stem, or neck, the apparatus will constitute an air-thermometer. For whenever the temperature of the external air changes, the air in the bulb of the mattrass must, by acquiring the same temperature, sustain a corresponding increase or diminution of bulk, and consequently, in a proportionable degree, influence the height of the liquid in the neck. This thermometer is very sensitive, and would be very accurate, but that it is as much influenced by the variations of atmospheric pressure as by thermometrical changes.

No. 4.—LABORATORY THERMOMETER.

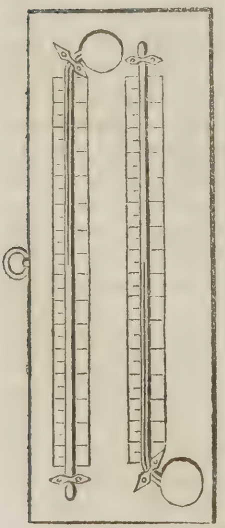


The thermometers used in laboratories, are usually constructed so as to have a portion of the wood, or metal, which defends them from injury, and receives the graduation, to move upon a hinge, as in the accompanying figure.

This enables the operator to plunge the bulb into fluids, without introducing the wood or metal, which would often be detrimental either to the process or to the instrument, if not to both.

The scale is kept straight, by a little bolt on the back of it, when the thermometer is not in use.

No. 5.—SELF-REGISTERING THERMOMETER.



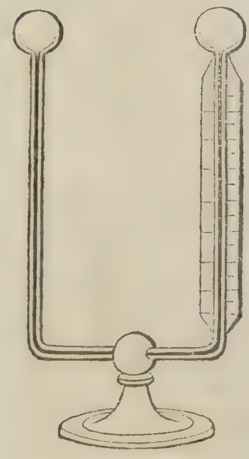
This figure represents a Self-Registering Thermometer.

It comprises necessarily a mercurial and a spirit thermometer, which differ from those ordinarily used, in having their stems horizontal, and their bores round: also large enough to admit a cylinder of enamel, in the case of the spirit thermometer, and a cylinder of steel, in the case of the mercurial thermometer. Both the cylinder of enamel and that of steel, must be as nearly of the same diameters with the perforations, in which they are respectively situated, as is consistent with their moving freely, in obedience to gravity, or any gentle impulse.

In order to prepare the instrument for use, it must be held in such a situation, as that the enamel may subside as near to the end of the alcoholic column as possible, yet still remaining within this liquid. The steel must be in contact with the mercury, but not at all merged in it.

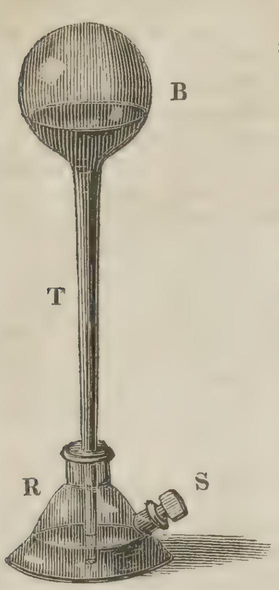
Under these circumstances, if, in consequence of its expansion, by heat, the mercury advance into the tube, the steel moves before it; but, should the mercury retire, during the absence of the observer, the steel does not retire with it. Hence, the maximum of temperature, in the interim, is discovered by noting the graduation opposite the end of the cylinder nearest the mercury. The minimum of temperature is registered by the enamel, which retreats with the alcohol when it contracts; but, when it expands, does not advance with it. The enamel must retire with the alcohol, since it lies at its margin, and cannot remain unmoved in the absence of any force competent to extricate it from a liquid, towards which it exercises some attraction. But, when an opposite movement takes place, which does not render its extrication from the liquid necessary, to its being stationary, the enamel does not accompany the alcohol; and hence the minimum of temperature, which may have intervened during the absence of the observer, is discovered, by ascertaining the degrees opposite to which is situated, the end of the enamel nearest to the end of the column of alcohol.

No. 6.—DIFFERENTIAL THERMOMETER.



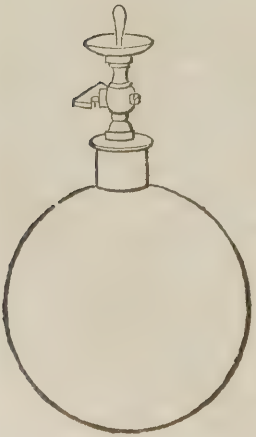
This instrument consists of a glass tube nearly in the form of the letter U, with a bulb at each termination. In the bore of the tube there is some coloured liquid, as for instance, sulphuric acid, alcohol, or ether. When such an instrument is exposed to any general alteration of temperature in the surrounding medium, as in the case of a change of weather, both bulbs being equally affected, there is no movement produced in the fluid; but the opposite is true, when the slightest imaginable calorific influence exclusively affects one of the bulbs. Any small bodies, situated at different places in the same apartment warmed by a fire, will show a diversity of temperature, when severally applied to the different bulbs of such an instrument.

No. 7.—DIFFERENCE BETWEEN AN AIR THERMOMETER AND A DIFFERENTIAL THERMOMETER, ILLUSTRATED UPON A LARGE SCALE.



The adjoining figure represents an instrument, which acts as an air thermometer, when the stopple S is removed from the tubulure in the conical recipient R; because in that case, whenever the density of the atmosphere varies either from changes in temperature, or barometric pressure, hereafter to be explained, the extent of the alteration will be indicated by an increase or diminution of the space occupied by the air in the bulb B, and of course by a corresponding movement of the liquid in the stem T. But when the stopple is in its place, the air cannot, within either cavity of the instrument, be affected by changes in atmospheric pressure: nor can changes of temperature which operate equably on both cavities, produce any movement in the liquid which separates them. Hence under these circumstances, the instrument is competent to act only as a differential thermometer, being apparently insensible to any change, which does not operate unequally upon its different cavities.

No. 8.—EXPERIMENTAL PROOF THAT AIR HAS WEIGHT.



By a temporary communication with an air pump, by means of a screw with which it is furnished, the globe represented is exhausted of air. It is then counterpoised upon a scale beam by weights with which it is exactly equiponderant. Being thus prepared, if the air be allowed to re-enter it, by opening the cock, the globe will preponderate; and if a quantity of water adequate to restore the equilibrium, be introduced into a small vessel duly equipoised by a counter weight applied to the other arm of the scale beam, the inequality, in bulk, of equal weights of air and water, will be satisfactorily exhibited. The addition of the

water is easily made by the chyometer, an instrument hereafter to be described.

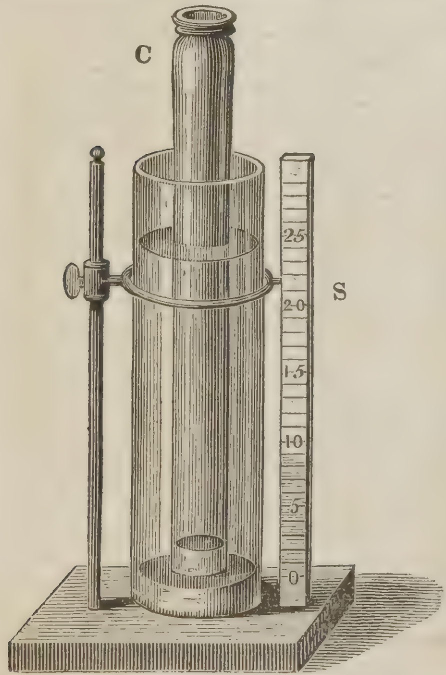
If, instead of allowing the globe to replenish itself as above described, it be screwed upon a graduated receiver, so as to draw in a certain number of cubic inches of any other gaseous fluid, the ratio of its weight to that of atmospheric air may be ascertained. Consequently by successive experiments, the respective weights of equal bulks of different gases, or in other words, their specific gravities may be determined.

No. 9.—A NEW METHOD OF DEMONSTRATING THE EXISTENCE AND THE EXTENT OF THE PRESSURE OF THE ATMOSPHERE.

PRELIMINARY PROPOSITION.

For the pressure of any fluid, on any area assumed within it, the pressure of a column of any other fluid may be substituted, making it as much higher as lighter, as much lower as heavier; or, in other words, the heights being inversely, as the gravities.

Experimental Illustration in the case of Mercury and Water.



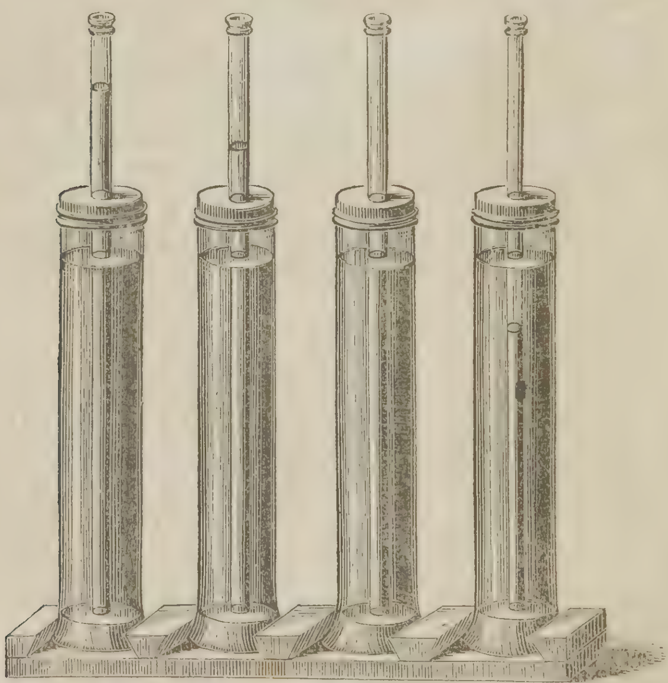
If into a tall glass jar, such as is represented in the adjoining figure, a glass cylinder, C (like a large glass tube open at both ends) were introduced, on filling the jar with water, this liquid would of course rise in the cylinder to the same height as in the jar; but, if, as in the figure, before introducing the water, the bottom of the jar be covered by a stratum of mercury, two inches deep, so as to be sufficiently above the open end of the tube, it must be evident, that the water will be prevented from entering the cylinder by the interposition of a heavier liquid. But as the pressure of the water on the mercury outside of the cylinder, is unbalanced by any pressure from water within the cylinder, the mer-

cury within will rise until, by its weight, the external pressure of the water is compensated. When this is effected, on comparing, by means of the scale S, the height of the two liquids, it will be seen that for every inch of elevation acquired by the mercury, the water has risen more than a foot; since the weight of mercury is, to that of water, as 13.6 to 1.

It may be demonstrated, that the pressure of the column of mercury is exactly equivalent to that of a column of water having the same base, and an altitude equal to that of the water in the jar, by filling the cylinder with water. It will then be seen, that when the water, inside of the cylinder, is on a level with the water, on the outside, that the mercury, within the cylinder, is also on a level with the mercury without.

It is therefore obvious, that the column of mercury, within the tube, is produced by the weight or pressure of the water without, and measures the extent of that pressure, on the lower orifice of the tube.

No. 10.—*The previous Illustration extended to the case of Liquids lighter than Mercury.*



LET there be four jars, each about four inches in diameter, and more than thirty inches in height—severally occupied by mercury to the depth of about two inches. In the axis of each jar, let a

tube be placed, of about one inch and a half, in diameter, and about one-fourth taller than the jar, with both ends open, and the lower orifice under the surface of the mercury. On pouring water into the jars, the mercury rises in the tubes, as the water rises in the jars; but the mercury rises as much less than the water, as it is heavier.

The mercurial columns, in this case as in the preceding experiment, owe their existence to the pressure of the surrounding water, and, by their height, measure the extent of that pressure on the areas, of their bases, respectively. They may be considered as substituted severally for the aqueous columns, which would have entered the tubes, had not the mercury been interposed. Accordingly, water being poured into one of the tubes, the mercury in that tube, subsides to a level with the mercury without; when the water (poured into the tube) reaches the level of the water without.

The three remaining columns of mercury, may be considered as substituted, in water, for columns of water, and being as much lower as heavier, are found adequate to preserve the equilibrium.

It remains to be proved, that other fluids, heavier, or lighter, than water, may in like manner be substituted for the columns of mercury, and of course for the water, of which the mercury is the representative.

Into the three tubes, in which, by the addition of water in the jars, columns of mercury are sustained, pour severally, ether, alcohol, (differently coloured, so that they may be distinguished) and a solution of sulphate of copper, until the mercurial columns, within the tubes, are on a level with the mercury without. It will be found, that the column formed by the cupreous solution, is much lower than the surface of the water on the outside of the tube: that the opposite is true of the column of alcohol; and that the ether (still more than the alcohol) exceeds the surrounding water in elevation.

While it is thus proved, that columns of mercury, ether, and alcohol, or of a saline liquid, may, in water, be substituted for columns of this fluid; it is also apparent, that they must be as much higher than it, as lighter; as much lower, as heavier; or in other words, their heights appear to be inversely as their gravities—which will hereafter be more accurately proved, by an instrument, which I have invented, called the Litrameter.

Pursuant to the law which has been thus illustrated, that the pressure of one fluid may be substituted for that of another; provided, any difference of weight, be compensated by a corresponding difference in height; if, in lieu of water, the mercury were pressed by air on the outside of the tubes, unbalanced by air within, a column of the metal would be elevated, which would be in proportion to the height, and weight, of the air thus acting upon it.

In order to show that the air exercises a pressure analogous to that of the water on the surface of the mercury, outside of the tubes, in the experiments just described, it is only requisite, that

this external pressure be unbalanced by the pressure of air within the tube.

This desideratum is obtained, by filling with mercury, a tube about three feet in length, open at one end, and closed at the other, and covering the open end with the hand, until it be inverted and merged in a vessel containing some of the same metal, without allowing any air to enter. A mercurial column of about 30 inches in height, will remain in the tube, which must be supported by the pressure of the surrounding air, and be an index of its weight. This is a case obviously analogous to that of the mercurial columns, supported by aquatic pressure, in the experimental illustration above afforded.

Supposing the base of the column of mercury, thus sustained by the atmosphere, were equivalent to a square inch, the total weight of the column would be about fifteen pounds. This of course represents the weight of that particular column of air only, whose place it has usurped; and as, for every other superficial inch in the earth's surface, a like column of air exists, the earth must sustain a pressure from the atmosphere, equal to as many columns of mercury, 30 inches high, as could stand upon it; or equal to a stratum of mercury, of the height just mentioned, extending all over the surface of the globe.

It has been shown, that the height of heterogeneous fluids, reciprocally resisting each other, are inversely as their gravities; or, in other words, that they are as much higher, as lighter, as much lower as heavier. The height of the column of air which, by its pressure, elevates the mercury, must, therefore, be as much greater than the height of the column of mercury, as the weight of the mercury is greater than the weight of the air; supposing the air of uniform density. Mercury is 11.152 times heavier than air, and of course the height of the atmosphere would be (if uniform in density) 11.152×30 inches $= 27.880$ feet; supposing 30 inches the height of the mercurial column supported.

Hence the atmosphere, if of the same density throughout, as on the surface of the earth, would not extend much above the elevation ascribed to the highest mountains.

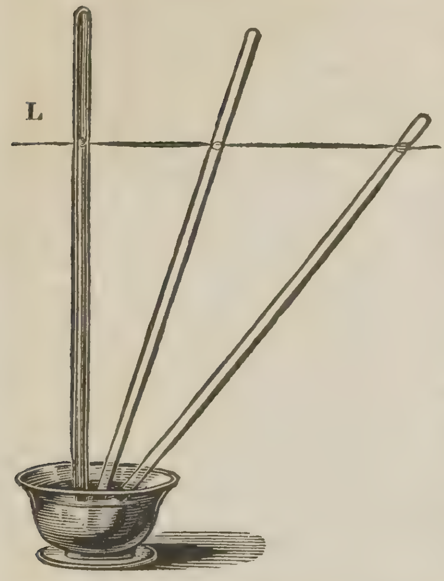
But as the pressure of the atmosphere causes its density, it may be demonstrated, that, the heights increasing in arithmetical progression, the densities will decrease in geometrical progression. Thus at an elevation of three miles the air being, by observation, one half as dense, as upon the earth's surface:

At 6 miles it will be	$\frac{1}{4}$	At 18 miles it will be	$\frac{1}{64}$
9 - - - - -	$\frac{1}{8}$	21 - - - - -	$\frac{1}{128}$
12 - - - - -	$\frac{1}{16}$	24 - - - - -	$\frac{1}{256}$
15 - - - - -	$\frac{1}{32}$	27 - - - - -	$\frac{1}{512}$
		30 - - - - -	$\frac{1}{1024}$

or, rarer than we can render it by the finest air pump.

These results have been verified, to a considerable extent, by actual observation.

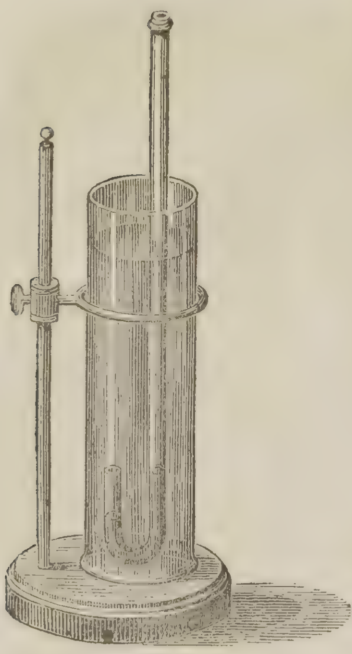
No. 11.—TORRICELLIAN EXPERIMENT.



THIS experiment, which we owe to the celebrated Torricelli, and which has received its name from that great philosopher, is illustrated by the following diagram. The tube filled with mercury and inverted in a vessel nearly full, of the same metal, may be *supposed* to occupy either of the three positions, represented in the drawing. The mercury, in each position, is represented as preserving the same degree of elevation, its surface being always in the same horizontal plane, or level, whether upright, or inclined—or *we may suppose* three tubes, filled with mercury, and inverted in a vessel, nearly full of the same metal, to be placed in the positions represented in the drawing. The upper surfaces of the columns of mercury in each tube, will be found always coincident with the same horizontal plane, however different may be the angle, which they make with the horizon. And the horizontal plane, in which their surfaces are thus found, will be between 27, and 31 inches, from the surface of the mercury in the vessel. The line L, with which the mercury in each of the tubes is on a level, represents a cord rendered horizontal, by making it parallel, to the surface of the mercury, in the reservoir.

No 12.—ADDITIONAL ILLUSTRATION OF ATMOSPHERIC PRESSURE.

I trust, that the preceding illustrations, are well qualified to convey a clear conception of atmospheric pressure: but as it sometimes happens, fortuitously, that when truth cannot get access to the mind under one form, it may reach it in another, even when less eligible, I subjoin the following illustration; which though much less interesting, and associating with it fewer instructive phenomena, is more brief, and perhaps not less conclusive.



If a tube, recurved into a crook at one end, so as to form a syphon, with legs of very unequal length, and both ends open, have the crook lowered into water, as in the adjoining figure, the fluid will, of course, rise within the tube, to the same height as without. But if, before the crook is sunk into the fluid, it be occupied by mercury, the water will enter the tube, only so far as the pressure which it exerts upon the mercury in the short leg of the syphon, is competent to raise the mercury in the other.

This pressure, or the effort of the water to enter the tube, is obviously measured by the height to which it forces the mercury, in the long leg of the syphon, above the mercurial surface, in the short leg. The height will of course be greater, or less, in proportion to the depth to which the lower surface of the mercury may be sunk. It will also be greater or less, accordingly, as the fluid in which it is immersed, is heavier or lighter. Hence, as water is about 820 times heavier than air, a depth of 820 inches in air, would displace the mercury, as much as one inch in water.

Let us imagine a tube recurved at one end, similarly to the one represented in the preceding figure, (the crook likewise occupied by mercury) to have the upper orifice as completely above the atmosphere, as the orifice of the tube is above the water in the jar. The mercury, in the short leg of the syphon, thus situated, would be evidently exposed to a pressure, caused by the air, analogous to that sustained from water, in the case of the tube, as already illustrated: and this pressure of the air would, as in the case of the water, be measured by the rise of the mercury, in the long leg of the syphon.

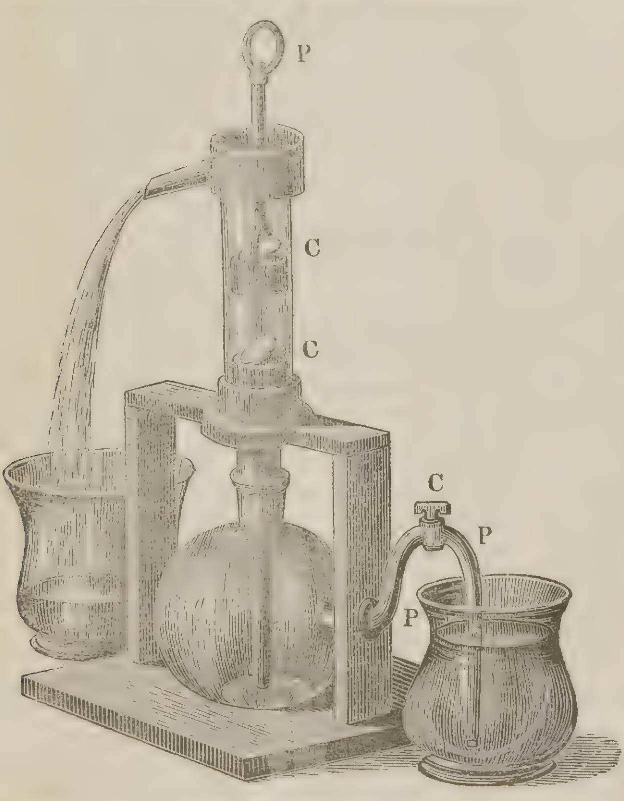
It is obviously impossible to realize this experiment, with a syphon, reaching above the atmosphere; but, as there would be no motive, for giving such a height to the syphon, unless that the mercury, in the long leg, should be inaccessible to atmospheric pressure, if this object can be otherwise attained, the phenomenon may be exhibited in the case of the atmosphere, without any material deviation.

In fact, to protect the mercury in the long leg, from atmospheric pressure, we have only to seal the orifice of that leg; and

through the orifice of the other, fill the syphon with mercury, before we place it in a vertical position. We shall then find, that the pressure of the air on the mercury, in the open leg of the syphon, will support a column of this metal in the other leg, of nearly thirty inches; though occasionally varying from 27 to 31 inches.

No. 13.—APPARATUS FOR ILLUSTRATING THE OPERATION OF THE WATER PUMP.

This figure represents an apparatus, as modified by me, for *the illustration of the action of the water pump, by suction, and the necessity of atmospheric pressure to its efficacy.*



A little suction pump is constructed, with a chamber, CC, of glass, which permits the action of its piston, P, and valves to be seen. Below the pump is a hollow glass globe filled with water. This globe communicates with the pump, by a tube visibly descending from the lower part of the pump, through an aperture in

the globe, till it reaches the bottom nearly. This tube is luted, air tight, into the aperture by which it enters the globe. Its orifice, next the chamber, is covered by a valve, opening upwards. In the axis of the piston, there is a perforation, also covered by a valve opening upwards.

If the piston, of this little pump, be moved alternately up and down, as usual in pumping, as often as it rises its valve will shut close, so that if nothing passes by the sides of the piston, nor enters into the chamber of the pump, from below, a vacuum must be formed behind the piston. Under these circumstances, it might be expected that the water would rise from the globe, through the lower valve, and prevent the formation of a vacuum. But being devoid of elasticity, and therefore incapable of self-extension, beyond the space which it occupies, the water does not rise into the chamber of the pump, so long as by closing the cock, C, of the recurved pipe, PP, communication with external air is prevented. But if this cock be opened, during the alternate movement of the piston, a portion of the water will mount from the globe into the chamber, at each stroke of the piston. The opening of the cock, permits the atmosphere to press upon the fluid in the globe, and to force it up the tube, leading to the pump chamber, as often as the chamber is relieved of the atmospheric pressure by the rise of the piston.

As soon as the piston descends, the valve, over the orifice of the tube, shuts, and prevents the water from getting back into the globe. It is of course forced through the perforation in the piston, so as to get above it. When the piston rises, the valve over its perforation being shut, it lifts the portion of water above this valve until it runs out, at the nozzle at the pump, while the chamber, below the piston, receives another supply from the globe. But if after all the water has been pumped, from the globe, the pumping be continued, *with the cock closed*, a portion of air will be removed from the globe, at each stroke, until the residue be so much rarefied, as, by its elasticity, no longer to exert against the valve, closing the tube, sufficient pressure to lift it; and thus to expand into the vacuity formed behind the piston, as often as it rises.

The rarefaction thus effected, in the air remaining in the globe, is rendered strikingly evident, by causing the orifice of the curved tube to be under the surface of some water in an adjoining vase, while the cock is opened. The water rushes from the vase into the exhausted globe, with great violence; and the extent of the rarefaction is demonstrated, by the smallness of the space, within the globe, which the residual air occupies, after it is restored to its previous density, by the entrance of the water.

No. 14.—CHEMICAL IMPLEMENT.

An Engraving and a Description of an Instrument for withdrawing, with facility, small portions of Liquids from situations otherwise less easily reached.

By means of a bag of caoutchouc, fastened upon the neck of a glass bulb, with a long tapering perforated stem, as in the annexed figure, an instrument may be constructed, of great use in a chemical laboratory.

In order to withdraw from any vessel into which the stem will enter, a portion of any contained liquid, it is only necessary to compress the bag so as to exclude, more or less of the air from within it; then place the orifice of the stem below the surface of the liquid, and allow the bag to resume its shape. Of course, the space within it, becoming larger, the air must be rarefied, and inadequate to resist the pressure of the atmosphere until enough of the liquid shall have entered to restore the equilibrium of density, between the air within the bag, and the atmosphere. The air within the bag cannot, however fully, resume its previous density; since the column of the liquid counteracts, as far as it goes, the atmospheric pressure. Indeed, this counteracting influence is so great, in the case of mercury, that the instrument cannot be used with this liquid. It is however the only substance, fluid, at ordinary temperature, which is too heavy to be drawn up into the bulb, of the instrument in question, when furnished with a stout bag.

No. 15.—OF THE AIR PUMP.

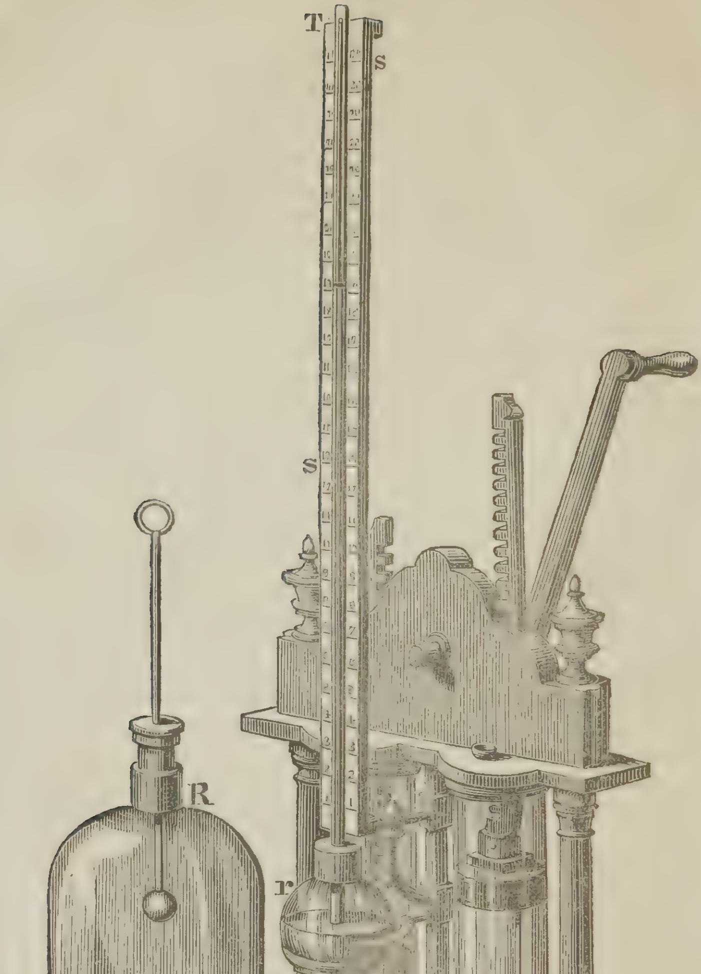
On the difference between the Air Pump and the Water Pump.

The action of the air pump, is perfectly analogous to that of the water pump; as there is no difference between pumping water and pumping air, which does not arise from the nature of the fluids; the one being elastic, the other almost destitute of elasticity.

In the air pump, as in the water pump, therefore, there is a chamber, and an upper and a lower valve; the operation of which, is analogous to that of the pump, which has been described, in the preceding article.

DESCRIPTION OF A LARGE AIR PUMP WITH GLASS CHAMBERS.

The following engraving represents a very fine instrument, of an unusually large size, obtained from Mr. Pixii, of Paris.


T
S
S
R
r
R

From the engraving, it must be evident that this pump has two glass chambers: they are unusually large, being nearly three inches in diameter inside. The lower valve, V, is placed at the end of a rod, which passes through the packing of the piston. Hence, during the descent of the piston, the friction of the packing, against the rod, causes it to act upon the valve with a degree of pressure adequate to prevent any escape of air, through the hole which it closes, at the bottom of the chamber. The air included between the piston, and the bottom of the chamber, is, therefore, by the descent of the piston, propelled through a channel in the axis of the piston, covered by a valve, opening upwards. When the motion of the piston is reversed, the air cannot, on account of the last mentioned valve, get back again into the cavity which the piston leaves behind it. But in the interim, the same friction of the packing, about the rod, which had caused it to press downwards, has now, in consequence of the reversal of the stroke, an opposite effect, and the valve, V, is lifted as far as a collar, on the upper part of the rod, will permit. The rise, thus permitted, is just sufficient to allow the air to enter under the valve through the orifice of a channel which it had closed, and which leads from a hole in the centre of the air pump plate; and of course from the cavity of the bell glass, RR, placed over it. The air of the bell, finding the resistance in this channel lessened, in consequence of the vacuity forming beneath the piston, moves into the chamber. By the next downward stroke of the pump, the air which has thus entered the chamber is propelled through the valve hole in the piston, as the air of the chamber had been propelled through this passage at first. Another upward stroke, expels this air from the upper portion of the chamber; and the valve attached to the rod being again uplifted, during the rise of the piston, the portion of the chamber, left below the piston, is supplied with another complement of air, from the bell glass: and thus a like bulk of air is removed at every stroke of the pump. I say a like *bulk* of air, since the *quantity* necessarily varies with the *density* of the air in the vessel subjected to exhaustion. This *density* is always directly as the *quantity* of air remaining; of course it finally becomes insignificant. Thus when the quantity, in the receiver, is reduced to $\frac{1}{100}$ of what it was at first, the weight of air removed, at each stroke, will be $\frac{1}{100}$ of the quantity taken at each stroke when the process began. I have spoken here only of the action of one chamber; but that of the other is exactly similar, excepting that while the piston of one goes down, that of the other goes up.

The gage represented in this engraving, is one which I have adopted upon a well known principle. That which accompanied the air pump was very precarious. Hence it reached me in bad order, and was too small for its indications to be seen by my class. The gage which I employ, consists of a globular vessel to hold mercury, supported upon a cock. The mercury is prevented from entering the perforation in the cock, by a tube of iron, surmounted

by a smaller one of varnished copper, which passes up into the axis of a Torricellian glass tube, till it reaches near the top. The tube opens, at its lower extremity, under the surface of the mercury in the globe. The exhaustion of this tube and that of any vessel placed over the air pump plate, proceed simultaneously, and consequently the mercury is forced up from the globe, into the glass tube, to an altitude, commensurate with the rarefaction.

By inspecting a scale, SS, behind the glass tube, the height of the mercury is ascertained. In order to make an accurate observation, the commencement of the scale must be duly adjusted to the surface of the quick-silver in the globe. On this account it is supported, by sliding bands, on an upright square bar, C, between the glass cylinders.

The bell glass, RR, represented on the air pump plate, is one which I usually employ, in exhibiting the artificial Aurora Borealis. The sliding wire, terminated by a ball, enables the operator to vary the distance, through which, the electrical corruscations are induced.

No. 16.—A LIQUID EXCLUDED FROM A BULB BY AIR, EXPANDED BY HEAT, OR RAREFIED BY EXHAUSTION.

A flask half full of water, is inverted in another vessel, having some water on the bottom, and both are placed, under a bell glass, on the plate of an air pump. As the air is withdrawn, from the bell, by the action of the pump, the air, included in the flask, enlarges its bulk, finally occupying the whole vessel, and partially escaping from the orifice, through the water in the lower vessel. When the atmosphere is allowed to re-enter the bell, the water rises into the flask, so as to occupy as much more space, than at first, as the air occupies less, in consequence of a portion having escaped as above-mentioned.

If the bell glass be removed, and a red hot fire should be approximated to the upper half of the flask, the liquid will be expelled from it, as in the preceding experiment.

It follows that the bulk of air sustains the same change, whether its temperature be increased, or the pressure of the atmosphere diminished.

No. 17.—EFFECT OF ATMOSPHERIC PRESSURE ON THE HAND.

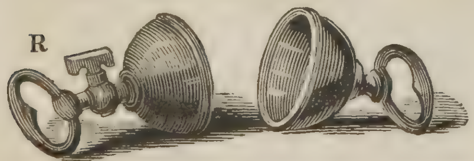
If, as represented in this figure, the air be exhausted from a vessel, covered by the hand, its removal will be found almost impracticable: for, supposing the opening, which the hand closes, to be equal to five square inches, the pressure on it will be seventy-five pounds.

No. 18.—BLADDER RUPTURED BY THE WEIGHT OF THE ATMOSPHERE.

Let there be a glass vessel, open at both ends, as in this figure. Over the upper opening, let a bladder be stretched, and tied, so as to produce an air tight juncture. For every square inch of its superficies, the bladder, thus covering the opening in the vessel, sustains a pressure of about fifteen pounds: yet this is productive of no perceptible effect; because the atmosphere presses upwards, against the lower surface, of the bladder, as much as downwards, upon the upper surface. But if the vessel be placed upon the plate of an air pump, so that, by exhaustion, the atmospheric pressure downwards, be no longer counteracted by its pressure upwards, the bladder will be excessively strained, and usually, torn into pieces.

When the bladder is too strong to be broken, by the unassisted weight of the air, a slight score, with the point of a penknife, will cause it to be ruptured, not only where the score is made, but in various other parts, so that it will be, at times, torn, all round, from off the vessel.

No. 19.—THE HEMISPHERES OF OTHO GUERICKE, THE CELEBRATED INVENTOR OF THE AIR PUMP.



Two brass hemispheres are so ground to fit each other at their rims, as to form an air tight sphere, when duly united. One of the hemispheres is furnished with a cock, on which is a screw for attaching the whole, to the air pump.—Being by these means exhausted, the cock closed, and the ring, R, screwed on to the cock, great force must be exerted by persons severally taking hold of the rings, before the hemispheres can be separated.

The area of the hemispheres, where united, being about four square inches, on each of which the atmosphere exerts a force of fifteen pounds, the whole resistance to the separation should equal sixty pounds.

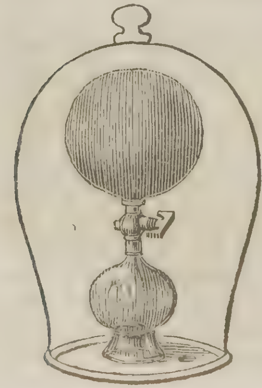
This experiment attracted great attention, when first performed by Otho Guericke, the inventor of the air pump.

No. 20.—AIR ENLARGES ITS BULK, IN PROPORTION AS THE SPACE ALLOTTED TO IT, IS ENLARGED.

The mode, in which the air occupying but a small part of a vessel may be rarefied, so as to occupy the whole cavity, is shown by the experiment represented in the annexed engraving. A bladder is so suspended within a vessel included in a receiver, R, that the cavity of the bladder, communicates, through its own neck and that of the vessel, with the cavity of the receiver; while no such communication exists between the receiver, and the space between the bladder and the inside of the vessel.

Things being thus situated, and the receiver exhausted, the bladder contracts, in consequence of the removal of air from the inside, proportionably with the exhaustion of the receiver: for, as the air between the outside of the bladder, and the inside of the vessel, is no longer resisted within the bladder, by air of a density equal to its own, it expands into the space which the bladder had occupied, so as to reduce it into a very narrow compass.

This cannot excite surprise, when it is recollected, that the air confined between the outside of the bladder, and the inside of the vessel, had, previously to the exhaustion, been condensed by supporting the whole atmospheric pressure, and must of course enlarge itself, from its elasticity, as that pressure is diminished.



This power, of any portion of included air to extend itself, in consequence of removal of pressure, is illustrated in another way, by subjecting to a highly rarefied medium a gum elastic bag, its orifice being previously closed, so as to be air-tight. The bag will swell up in a most striking manner, in proportion to the diminution of power in the air without the bag, to counteract the reaction of the air within it.

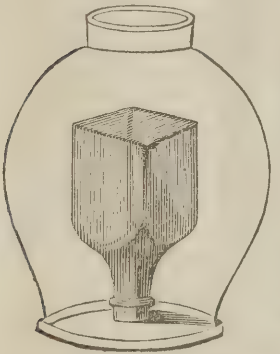
The experiment is reversed by subjecting a bag, while inflated, to the influence of a condenser, by which it may be reduced in size more than it had been expanded, because the pressure, in the case

of exhaustion, never can exceed that of the atmosphere, while in that of condensation, it may be so increased as to fracture any glass receiver.

In the preceding cut, the gum elastic bag is represented as when inflated. The glass represented below the bag, is one which happened to be used as a support, when the drawing was made.

No. 21.—BOTTLE BROKEN BY EXHAUSTION OF THE AIR FROM WITHIN.

Proof that Atmospheric Pressure on the outside of a square Glass Bottle, will break it, as soon as it ceases to be counteracted by the resistance of the Air within.

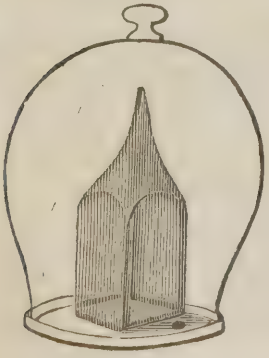


The mouth of a square bottle, being placed over the hole in an air pump plate, so as to be sufficiently tight for exhaustion, a few strokes of the pump, by withdrawing the air from the interior, causes the bottle to be crushed with violence.

A stout globular glass vessel, with an aperture at top, is placed over the bottle, to secure the spectators from the fragments.

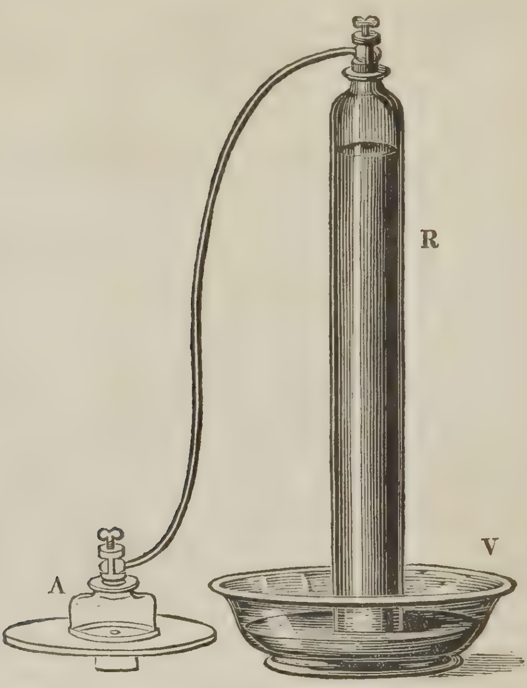
No. 22.—BOTTLE BROKEN BY EXHAUSTION OF THE AIR FROM WITHOUT.

The elastic reaction of the Air, confined within a square Bottle, will burst it, as soon as relieved from the counteracting weight of the Atmosphere.



If a thin square bottle, so sealed, that, while unbroken, the contained air cannot escape, be placed within the receiver of an air pump, the exhaustion, of the receiver, will cause the fracture of the bottle.

No. 23.—MERCURIAL COLUMN ELEVATED BY EXHAUSTION.



R is a glass receiver about 33 inches in height, with a perforated neck, into which a brass gallows screw is cemented; so that by means of the flexible pipe communicating with the air pump plate A, the receiver may be exhausted. The mouth of the receiver being immersed in mercury, in the vase, V; as the exhaustion proceeds, the metal rises in the receiver, until it reaches more or less nearly to the height, at which it stands in a Torricellian tube, accordingly as the pump is more or less perfect.

The elevation of a large column of a liquid, so heavy as that in this case employed, merely by atmospheric influence, is very pleasing to the beholder.

No. 24.—BAROMETRIC COLUMN OF MERCURY, LOWERED BY EXHAUSTION.

It has been shown, that in a tube void of air, a mercurial column may be supported nearly at the height of thirty inches; and this has been alleged to result from the pressure of the atmosphere on the surface of the mercury without the tube.

In order to verify this allegation, let a tube, supporting within it a column of mercury, be placed, under a competent receiver, upon the air pump plate.

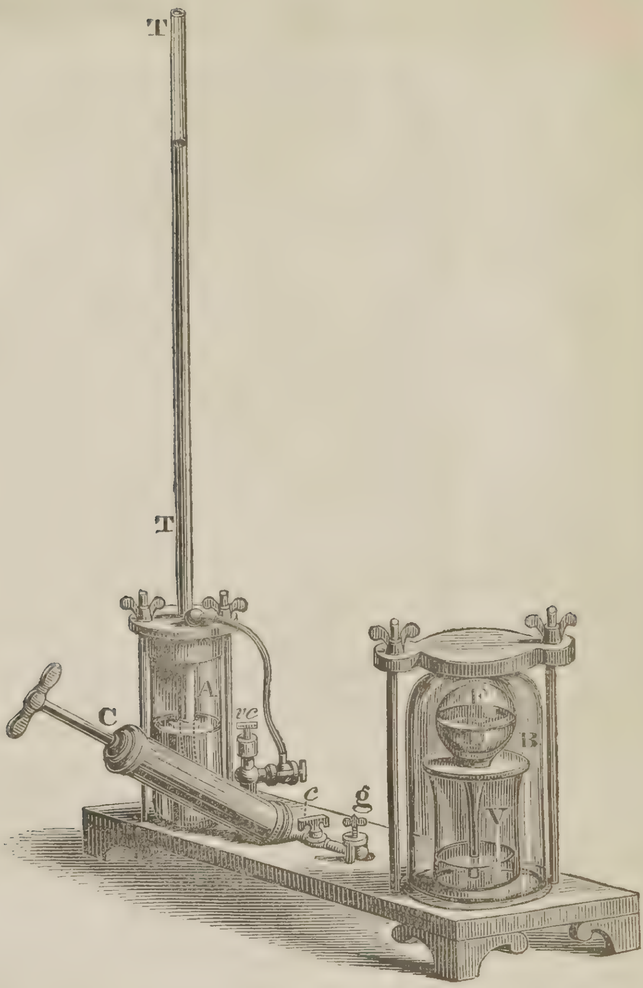
It will be found, that, as the air is withdrawn from the receiver, the mercury in the tube is lowered; and if the exhaustion be carried far enough, will sink to a level with the mercury on the outside.

If, at the same time that the air is withdrawn from the outside of a tube, as above, a communication exist between the air pump, and the inside of another tube, the upper end sealed, the lower opened and immersed in mercury, as in the case of the gage tube of the air pump, a column of the metal will rise in this tube, while it sinks in the other: thus proving, that the force which is required to remove the air from the outside of the tube, as in the case first mentioned, is adequate to raise in another tube, a mercurial column, in height, equivalent to that, which is reduced.

No. 25.—INFLUENCE OF PRESSURE ON THE BULK OF AIR, AND OF ITS DENSITY, ON ITS RESISTANCE.

Air lessens, in bulk, as the pressure which it sustains augments; and the resistance, arising from its elasticity, is augmented; as the quantity, confined in the same space, is increased, or the confining space diminished.

This proposition is illustrated by the apparatus (contrived by me) represented in the following page.



If mercury be poured into the air tight vessel, A, through the tube, TT, which passes perpendicularly into this vessel until it touches the bottom, as the air, in the vessel, cannot escape, it resists the entrance of the mercury from the tube, so that an increasing column will be upheld, which by its height indicates the resistance. When the air in the vessel has been reduced to one half its previous volume, the height of the mercury in the tube will be about 30 inches, or equal to that of the mercury in the barometer, at the time of performing the experiment. Thus it is shown, that when air is condensed into half the space which it occupies under

the pressure of the atmosphere, its reactive power is doubled, being adequate to support a column of mercury, equal to the pressure of the atmosphere, in addition to that pressure. It follows, that the quantity of air in any space is as the compressing force—or what is the same thing, as the height of the column of mercury which it can support, in a Torricellian tube, to the height of the mercury in the barometer: and likewise, that the resistance of included air increases, with the diminution of the space allotted to it; or, vice versa, that the space, which the same portion of air occupies, lessens as the force compressing it increases.

It remains to be shown, that the *resistance* of air, to compression, *increases* as the *quantity* in any space *increases*.

If, by means of the condenser, C, (the valve cock, *vc*, and the cock, *c*, being opened,) air be injected into the vessels, A and B, at the same time, it will be found that the liquid in the vase, V, will mount into the flask, F, and that when the pressure is adequate to cause the air in this to be reduced to one half its previous volume, the mercury in the tube, TT, will have the same height as in the previous experiment, because the density of the air, and of course its quantity and reactive power, is doubled in this case, no less than in the last.

The communication between the condenser, and the receiver, A, is suspended during the first mentioned experiment, by closing the valve cock, *vc*. This cock is opened during the action of the condenser in the second experiment; and likewise another cock at C, which serves to intercept the communication between the condenser and the receiver, B. The gallows, *g*, enables the operator to remove (for the purpose of cleansing or repairing) the brass casting into which the condenser screws, to which the cocks are fastened, and which comprises the channel of communication between the receivers.

The valve cock, *vc*, is used in preference to one of the ordinary construction, because it may be relied upon, to produce a perfect degree of tightness: which common cocks are rarely capable of preserving, especially in opposition to great pressure.

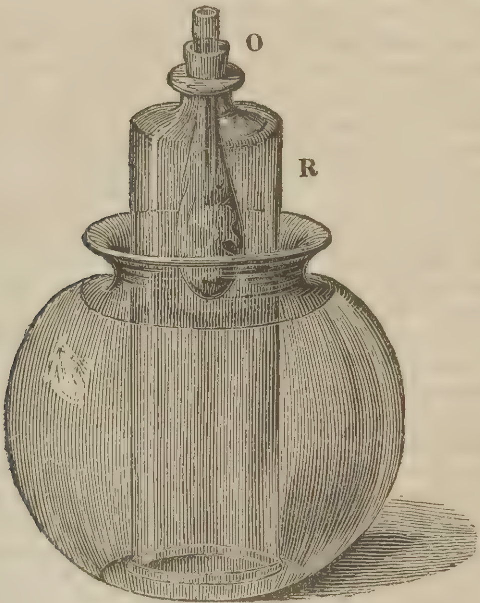
PROCESS OF RESPIRATION.

This process is described in the Minutes, nearly as follows:—

"The elevation of the sternum rarefies the air in the cavity of the thorax. Consequently, the atmospheric pressure not being adequately resisted, the external air rushes through the trachea into the lungs, dilating all its cells. The depression of the sternum and consequent diminution of the cavity, causes the air which had thus entered, or an equivalent portion, to flow out."

For the illustration of the process here described, I devised the following experimental illustration:—

No. 26.—MECHANICAL ACTION OF THE ANIMAL ORGANS IN RESPIRATION, ILLUSTRATED.



A TALL receiver, R, with an orifice, O, like a bottle, is placed in a globe of water, so that about two-thirds of the receiver is occupied by this liquid, the remainder with air—whilst a bladder is so suspended from the orifice, as not to touch the water.

The atmosphere has access to the cavity of the bladder, through its neck, and the orifice, O, of the receiver, but not to the space between the bladder and the receiver. When the receiver is lifted, the external air rushes into the bladder and inflates it. When the receiver is depressed, to its previous situation, the bladder resumes its previous state.

RATIONALE.

It has been proved, by the preceding experiments, that the force, which air opposes to compression, is inversely as the space, into which it may be compressed; and hence, that as the containing space is lessened, the resistance of the air is increased; as the containing space is enlarged, the aërial resistance is diminished.

Let us call the space bounded by the outer surface of the bladder, the inner surface of the receiver, and the upper surface of the water, A. Let the space, within the bladder, be called B.

Since the space B, is open to the atmosphere, it must be sub-

ject to atmospheric pressure, and exercise a reaction on every side equivalent to that pressure. The air must be in equilibrio, as to its reaction, with that in the space A; since there is nothing, but the flexible bladder, to interfere with the equilibrium.

The first effect of the elevation of the receiver, is to cause a minute enlargement of the space, A. The enlargement is but *minute*, because the reaction of the air, in A, must be lessened in proportion to the enlargement, and as soon as the reaction of the air in A becomes so much less than that of the air in B, as to create a difference adequate to overcome the feeble resistance of the bladder, the space, B, will be enlarged at the expense of A. Or, in other words, the bladder must be inflated. Hence, the inflation of the bladder and the rise of the receiver are apparently simultaneous. As an enlargement of the space, A, enables the air in B to inflate the bladder, so the enlargement of the space, B, consequent to this inflation, by reducing the density of the air in it, a little below that of the atmosphere, enables the latter to enter through the neck of the bladder.

Since when the receiver is lifted, the space A is enlarged, during the descent of the receiver, it must be diminished. As in the former instance, the density of the air in A is so much lessened, as to allow the bladder to be inflated; so in the latter case, the density is so much increased, beyond that of the air in B, as to compress the bladder, and force the air which had entered it to escape by the orifice, through which it had obtained admission.*

No. 27.—INFLUENCE OF PRESSURE ON THE AERIFORM STATE.

The following Experiments show that Pressure opposes and limits chemical action, where elastic Fluids are to be generated, or evolved.

Water heated to ebullition in a glass vessel, having ceased to boil in consequence of its removal from the fire, is made to boil again in an exhausted receiver.

* The water evidently must rise within the receiver, in proportion as the air which it contains is, by rarefaction, rendered incompetent to counteract the pressure of the atmosphere on the surface of the water without: but the movement, thus arising, does not essentially affect the explanation of the other phenomena—and is scarcely worthy of notice—since it is arrested almost at the outset, by the influence of the air, which enters the bladder, in affording a limit to the rarefaction.

No. 28.—CULINARY PARADOX.

Ebullition by Cold.

The water, in the inverted matrass here represented, is made to boil, by removing the vessel from its stand and placing it, with its neck uppermost and the mouth open, over a sand bath, till sufficient steam has been evolved to expel the atmospheric air. The mouth is then closed so as to be perfectly air tight, and the vessel replaced upon its stand. A partial condensation of the steam, soon follows, from the refrigeration of that portion of the glass which is not in contact with the water. The pressure of the steam upon this liquid of course becomes less, and its boiling point is necessarily lowered. Hence it begins again to present all the phenomena of ebullition; and will continue boiling, for a long time, if left to itself.

By the application of ice, or of a sponge soaked in cold water, the ebullition is accelerated; because the aqueous vapour, which opposes it, is in that case more rapidly condensed: but as the caloric is at the same time more rapidly abstracted, from the water, by the increased evolution of vapour, to replace that which is condensed, the boiling will cease the sooner, in consequence of a more active expenditure of caloric.

No. 29.—AERIFORM STATE DEPENDANT ON PRESSURE.

Proof that some Liquids would always be Aëriform, were it not for the Pressure of the Atmosphere.

A glass flask, being nearly filled with coloured water, the remaining space occupied by about half a gill of sulphuric ether, is inverted in a glass jar, covered at bottom by a small quantity of water, to prevent the air from entering the neck of the flask. The whole being placed upon the air pump plate, under a receiver, and the air exhausted, the ether assumes the aëriform state, and displaces the water from the jar. Allowing the atmospheric air to re-enter the receiver, the ethereal vapour is condensed into its previous form, and the water reoccupies its previous situation in the flask.

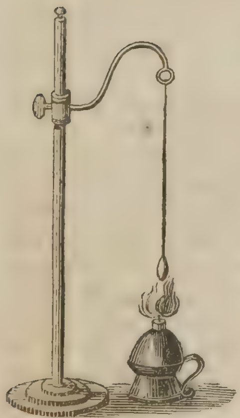
The return of the ether, to the state of liquidity, is more striking, when mercury is employed; though, in that case, on account of the great weight of this metallic liquid, the phenomenon cannot be exhibited, on so large a scale, without difficulty.

RATIONALE.

The particles of the ether, and those of the caloric, in the adjoining medium, are incessantly endeavouring to approach each other; yet, more than a certain number, of the particles of caloric, cannot enter the ether; because, those that are already in union with it, repel the rest. On the other hand, the ethereal particles cannot move outwards, towards those of the caloric, without overcoming the external pressure of the atmosphere, and assuming the aëriform state. Hence, while subjected to the pressure of the air, it remains liquid—but becomes gaseous, as soon as relieved from constraint.

This explanation may, of course, be extended to the ebullition of other liquids, in vacuo, at temperatures lower, than those at which they boil, in the air. It is obviously applicable to the two preceding illustrations—Nos. 27 and 28.

No. 30.—EXPLOSIVE POWER OF STEAM.



If a small glass bulb, hermetically sealed, while containing a small quantity of water, be suspended by a wire over a lamp flame, an explosion soon follows, with a violence and noise which is surprising, when contrasted with the quantity of water, by which it is occasioned.

RATIONALE.

Supposing that the bulb were, in the first instance, merely filled with steam, without any water in the liquid form, the explanation of this phenomenon would be comprised in the theory of expansion given page 2. In that case, the effort of the steam to enlarge itself, would be nearly in direct arithmetical proportion to the temperature; but when liquid water is present, while the expansive power of the steam, previously in existence, is thus increased, more steam is generated, with a like increased power of expansion. It follows, that the increments of heat being in arithmetical proportion, the explosive power of the confined vapour will increase geometrically, being actually doubled, as often as the temperature is augmented, somewhat less than 40 degrees, (F).

No. 31.—BOILING POINT RAISED BY PRESSURE.

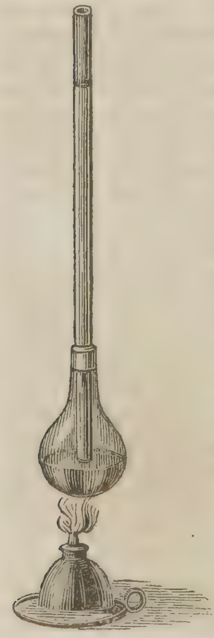
As the Boiling Point is lowered by a diminution of Pressure, so it is raised if the Pressure be increased.

INTO a small glass matrass,* with a bulb, of about an inch and a half in diameter, and a neck, of about a quarter of an inch in bore, introduce about half as much ether, as would fill it. Closing the orifice, with the thumb, hold the bulb over the flame of a spirit lamp, until the effort of the generated vapour, to escape, becomes difficult to resist,—removing the matrass, to a distance from the lamp, lift the thumb from the orifice: the ether, previously quiescent, will rise up into a foam, produced by the rapid extrication of its vapour.

This experiment may be performed more securely by employing a vessel of hot water, instead of a flame, to warm the matrass.

No. 32.—COLUMN OF MERCURY RAISED BY VAPOURIZED ETHER.

An increase of Pressure results from constrained Ebullition.

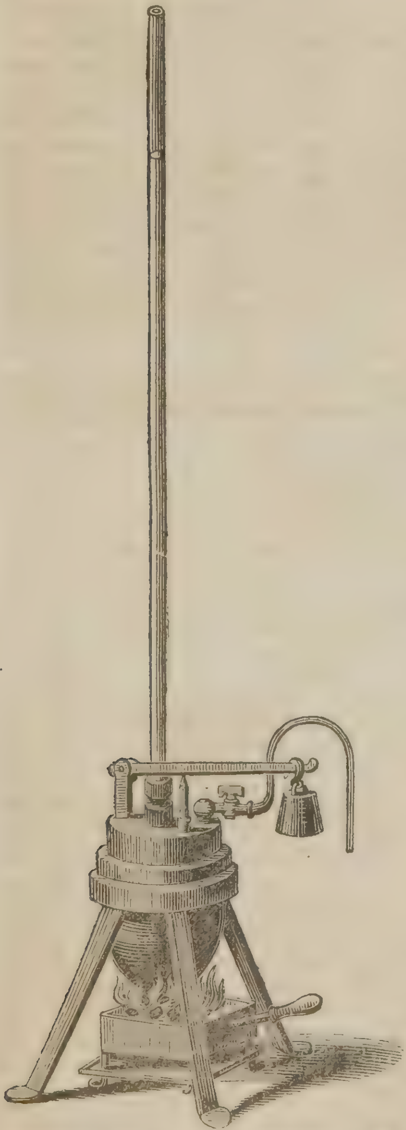


HAVING supplied a small flask, with a small quantity of mercury, and a minute portion of sulphuric ether; through the neck, let there be a glass tube, so introduced, and firmly luted, as that it may be concentric with the vertical axis of the vessel, and extend downwards until nearly in contact with the bottom. If the flask thus prepared, be subjected, cautiously, to a spirit lamp, the ether will be more or less converted into vapour; the vapour being unable to escape, will soon cause the mercury to rise to the top of the tube. On the removal of the lamp, the mercury falls to its previous situation.

* Matrass is a name given, by chemists, to a globular vessel, with a neck, in shape, resembling a Florence flask.

No. 33.—HIGH PRESSURE BOILER.

That the temperature of Steam is directly, as the pressure, may be demonstrated by a small Boiler, such as is represented in the following cut.



The glass tube, in the axis, passes below the water in the boiler, and enters a small quantity of mercury on the bottom. The juncture of the tube, where it enters the boiler, is made perfectly tight; and on the opposite side of the boiler, a tube, not visible in the drawing, descends into it. This tube consists of about two inches of a musket barrel, and is closed at bottom. The object of it is to contain some mercury, into which the bulb of a thermometer may be inserted, for ascertaining the temperature.

When the fire shall have been applied during a sufficient time, the mercury will have risen in the glass tube, so as to be visible, above the boiler; and continuing to rise, during the application of the fire; it will be found, that with every sensible increment, in its height, there will be a corresponding rise in the mercury of the thermometer.

In front of the tube there may be observed (in the drawing) a safety valve, with a lever and weight, for regulating the pressure.

It has been found, that, when the effort made by the steam to escape, in opposition to the valve thus loaded, is equal to about fifteen pounds for every square inch, in the area of the aperture: the height of a column of mercury, subjected to the same pressure of steam, is about equal to that of the column of this metal usually supported by atmospheric pressure in the tube of a barometer. The

pressure of the steam is, of course, about equal to that of the atmosphere. Hence the boiler, in this predicament, is alleged to sustain a pressure of one atmosphere; and, for every additional fifteen pounds per square inch, required upon the safety valve to restrain the steam, another atmosphere is conceived to be added. To produce such an increment of pressure, only requires an augmentation of 38 degrees in heat. To raise the pressure, to four atmospheres, the temperature of about 293 degrees, is sufficient—for eight atmospheres, about 343 degrees.

When, by means of the cock, an escape of steam is allowed, a corresponding decline of the temperature and pressure ensues.

If the steam, as it issues from the pipe, be received under a portion of water of known temperature and weight, the consequent accession of heat will appear surprisingly great when contrasted with the accession of weight, derived from the same source.—It has in fact been ascertained, that one volume of water converted into aqueous vapour, will, by its condensation, raise 9 volumes of water in the liquid form, one hundred degrees.

No. 34.—OF THE STEAM ENGINE.

The principle of Savary's Steam Engine illustrated.

A MATRASS, situated as in the above figure, and containing a small quantity of water, being subjected to the flame of a lamp, the water will soon, by boiling, fill the matrass with steam. When this is accomplished, bubbles of air will cease to escape from the neck of the matrass, through the water in the vase.

The apparatus being thus prepared, on removing the lamp, the water of the vase will quickly rush into the vacuity, in the matrass, arising from the condensation of the steam.

Of Savary's Engine.

The celebrated engine of Savary, which led to the invention of that of Newcomen, and finally to the almost perfect machine of

Bolton and Watt, consisted essentially of a chamber into which steam, after being introduced from a boiler, was condensed by a jet of cold water, as in the experiment above described.

Just before the condensation of the steam, the communication with the boiler was shut off, and a cock, or valve, was opened in a pipe descending into a reservoir of cold water. The chamber was consequently filled with water, which was expelled through an aperture opened for the purpose, by allowing the steam to enter again above the water. The aperture through which the water escaped, and that through which the steam entered, being closed simultaneously, the operation of condensing the steam and filling the chamber with water was reiterated, as likewise in due succession the other steps of the process, as above stated.

Of Newcomen's Engine.

The great objection to Savary's engine, was the waste of steam arising from its entrance, over the water, into a cold moist chamber. So great is the power of cold water in condensing steam, that had the steam been introduced, below the water, it could not have been expelled until ebullition should have been excited; but heat, as we shall soon show, being propagated downwards in liquids with extreme difficulty, the steam entering from above was not condensed so rapidly as to paralyze the engine.

To diminish the very great loss sustained in the engine of Savary, Newcomen, instead of causing the vacuum produced by the condensation to act directly upon water, contrived that it should act upon a piston, moving, air tight, in a large cylinder, like a pump chamber. The piston was attached to a large lever, to the end of which, on the other side of the fulcrum, a pump rod and a weight were fastened. By the vacuum arising from the condensation, the piston, being exposed to the unbalanced pressure of the atmosphere, was forced down to the bottom of the cylinder, drawing up, of course, the rod and weight at the other end of the lever.

The cylinder being replenished with steam, the weight on the beam drew up the piston in the cylinder, and pushed down the pump rod, and thus by the alternate admission and condensation of steam, the piston and pump rod were made to undergo an alternate motion, by which the pump, actuated by the rod, was kept in operation. Although less caloric was wasted by Newcomen's engine than by Savary's, there was still great waste, as the cylinder was to be heated up to the boiling point each time that steam was admitted, and to be cooled much below that point as often as condensation was effected.

Watt's Engine.

At this stage of the invention, Mr. James Watt, who combined, in an uncommon degree, mechanical ingenuity with philosophical knowledge, discovered that to produce a vacuum in a vessel replete with steam, it is only necessary to open a communication with a

vessel which is duly refrigerated. This being done, the vapour passes almost entirely into the latter. Hence his contrivance of a condenser into which the steam passes from the cylinder in which the piston moves. The necessity of cooling the cylinder at each reversal of the stroke, being obviated, the improvement of admitting the steam alternately above and below it became admissible. In Newcomen's engine, the steam was acting only half the time; in that of Watt, while the steam is entering above the piston, it is condensed below it—while it is entering below, it is condensed above.

Of the High Pressure Engine.

The only material difference between the operation of the high pressure engine, and that above described, is, that the steam escapes alternately, from above, and below the piston, into the air, instead of passing into a condenser.

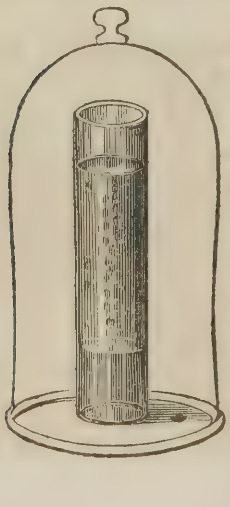
The steam in these engines acts simply by its explosive power; it is therefore necessary that there should be greater strength than in engines working with a condenser.

The engines in our steam boats generally combine the two principles—using steam which will support a weight of from seven to fifteen pounds per square inch.

A true Bolton & Watt steam engine cannot explode while the safety valve is free.

No. 35.—INFLUENCE OF PRESSURE ON THE ESCAPE OF GASEOUS SUBSTANCES FROM COMBINATION.

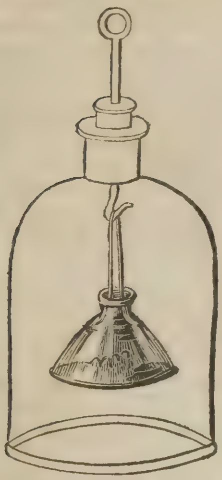
When one of the ingredients of a Solid or Liquid is prone to assume the aëriform state, its extrication will be more or less easily effected, in proportion, as the Pressure of the Atmosphere is increased, or diminished.



If a tall cylindrical jar, containing a carbonate, undergoing the action of an acid, be exhausted by the air pump, the effervescence will be augmented. But if, on the other hand, the same mixture be placed in a receiver, in which the pressure is increased, by condensation, the effervescence will be checked. In the one case, the effort which the carbonic acid makes to assume the gaseous state, is repressed; in the other, it is facilitated. Hence the necessity of condensation, in the process for manufacturing mineral water. Beyond an absorption of its own bulk of the gas, the affinity of the water is inadequate to subdue the tendency of the acid to the aëriform state; but when, by exterior mechanical pressure, a great number of volumes of the gas are condensed, into the

space, ordinarily occupied by one, the water combines with the same bulk of the condensed gas, as if it had sustained no condensation.

No. 36.—WATER FROZEN BY BOILING ETHER.



Let a portion of water, just adequate to cover the bottom, be introduced into the vessel, represented, in the subjoined drawing, as hanging within a receiver. Over the water, let a stratum of ether be poured, from an eighth to a quarter of an inch in depth. If, under these circumstances, the receiver be placed on the air pump plate, and sufficiently exhausted, the water freezes.

RATIONALE.

While the particles of the ether are pressed by the weight of the atmosphere, their attraction for caloric is incompetent to cause a union with a quantity of it, adequate to sustain them in the aëriform state; but, when they are no longer subjected to any extraneous cause of approximation, they are at liberty to indulge their partiality for that self-repellent fluid. Under these circumstances they attract caloric more powerfully, than water; and consequently, will cause the congelation, of any portion of this liquid, to which they may have access, by abstracting the principle, to which it owes its fluidity.

No. 37.—COLD CONSEQUENT TO RAREFACTION: OR RELAXATION OF PRESSURE.

Cold and Cloudiness arising from Rarefaction.

Incipient rarefaction in the air of a receiver is usually indicated by a cloud, which disappears when the exhaustion has proceeded beyond a certain point. A delicate thermometer placed in the receiver, shows that a decline of temperature accompanies this phenomenon. We may therefore infer, that the cloud is the consequence of refrigeration. But, in the present state of our knowledge, it is nearly as difficult to account for the disappearance of heat, as for the appearance of the cloud. This phenomenon, in common with many others, must be referred to those unknown peculiarities which determine the capacities of substances for caloric. By rarefaction the capacity of air for caloric, from some in-

scrutable cause, becomes greater than that of the aqueous vapour which it contains. This vapour being consequently deprived of it, condenses into a fog. The aqueous particles, receiving heat subsequently from the surrounding medium through the receiver, and air pump plate, are vapourized again; and of course, cease to be visible, in the form of a cloud.

No. 38.—*Cold produced by the Palm Glass.*

Two bulbs are formed, at each end of a tube, one having a perforated projecting beak. By warming the bulbs, and plunging the orifice of the beak into alcohol, a portion of this fluid enters, as the air within contracts, by returning to its previous temperature. The liquid, thus introduced, is to be boiled in the bulb which has no beak, until the whole cavity of the tube, and of both bulbs not occupied by liquid alcohol, is filled with its steam.

While in this situation, the end of the beak is to be sealed, by fusing it in a flame excited by a blowpipe.

As soon as the instrument becomes cold, the steam which had filled the space within it, vacant of alcohol in the liquid form, condenses, and a vacuum is produced; excepting a slight portion of vapour, which is always emitted by liquids when relieved from atmospheric pressure.

The instrument, thus formed, has been called a palm glass; because the phenomena, which it displays, are seen by holding one of the bulbs, in the palm of one of the hands.

When thus situated, the bulb in the hand being lowermost, an appearance of ebullition always ensues in the bulb, exposed to view, in consequence of the liquid, or alcoholic vapour, being propelled into it from the other bulb subjected to the warmth of the hand.

This phenomenon is analogous to the case of ebullition in vacuo, or the culinary paradox; but the motive for referring to the experiment here, is to state, that as soon as the last of the liquid is forced from the bulb, in the hand, a very striking sensation of cold, is experienced by the operator.

This cold is produced by the increased capacity of the residual vapour for caloric, in consequence of its attenuation. The analogy is evident between this phenomenon and that above described, both being attributable to the increase of capacity for caloric, resulting from a diminution of density.

Relaxation of Pressure.

It is immaterial whether the diminution of density, arise from relieving condensed air from compression, or from subjecting air of the ordinary density to rarefaction. A cloud similar to that which has been described as arising in a receiver partially exhaust-

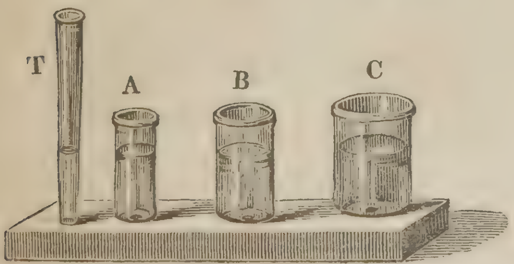
ed, may usually be observed in the neck of a bottle recently uncorked, in which, in consequence of its generation by fermenting liquor, a quantity of gas has been evolved disproportionable to the space.

No 39.—*Apparatus contrived by the Author for showing the influence of Relaxed Pressure, on the capacity of Air for Heat, or Moisture.*

I have contrived an apparatus for showing the influence of compression, on the capacity of air for caloric and moisture. A glass vessel with a tubulure and a neck, has an air thermometer fastened air tight by means of a cork into the one, while a gum elastic bag is tied upon the other, as represented in this figure. Before closing the bulb, the inside should be moistened. Under these circumstances, if the bag, after severe compression by the hand, be suddenly released, a cloud will appear within the bulb, adequate in the solar rays, to produce prismatic colours. At the same time the thermometer will show that the compression is productive of warmth—the relaxation of cold.

The tendency in the atmosphere to cloudiness, at certain elevations, may be ascribed to the rarefaction which air inevitably undergoes, in circulating from the earth's surface to such heights.

No. 40.—APPARATUS, CONTRIVED BY THE AUTHOR, FOR ILLUSTRATING CAPACITIES FOR HEAT.

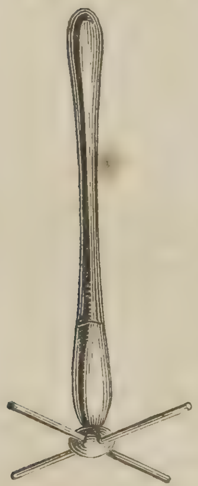


Let the vessels A B & C be supplied with water through the tube T. The water will rise to the same level in all. Of course the resistance made by the water in each vessel to the entrance of more of

this liquid will be the same, and will be measured by the height of the column of water in the tube T. Hence if the height of this column were made the index of the quantity received by each vessel, they would all have received the same quantity. But it must be obvious, that the quantities severally received, will be as different as are their horizontal areas. Of course we must not assume the resistance exerted by the water within the vessels against a further accession of water from the tube, as any evidence of an equality in the portions *previously* received by them.

In like manner, the height of the mercury in the thermometer, shows the resistance which substances, whose temperatures it measures, are making to any further accession of caloric: but it does not demonstrate the quantities, respectively received by them, in attaining to the temperature in question. This varies, in them, in proportion to their attraction for this self-repellent fluid; as the quantities of water, received by the vessels A B C, is varied in the ratio of their respective areas.

No. 41.—INEQUALITY OF CONDUCTING POWER.



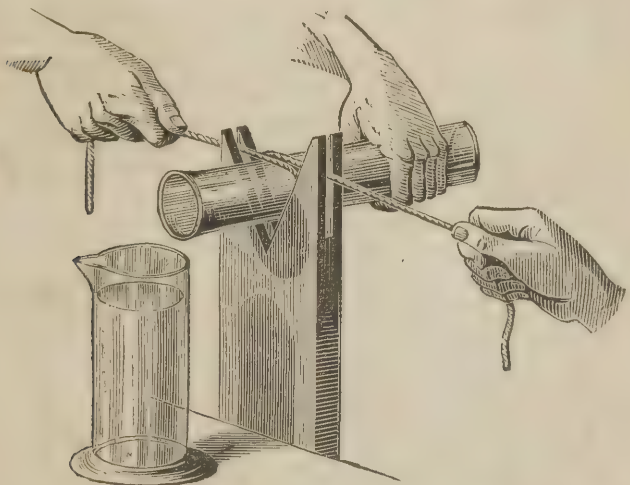
If we cement, to a ball of sealing-wax, fastened at the end of a wooden handle, one of the ends of each of four little rods, formed, severally, of metal, wood, glass, whalebone; on subjecting, successively, their other ends to the flame of a lamp, it will be found, that the metal becomes quickly heated throughout, so as to fall off from the wax—but, that the wood,or whalebone, may be destroyed, and the glass bent, by the ignition, very near to the wax, without melting it, so as to liberate them.

No. 42.—HEAT PRODUCED BY FRICTION.

Glass so heated by the friction of a cord as to separate into two parts, on being subjected to cold water.

Some years ago, Mr. Lukens showed me, that a small phial, or tube, might be separated into two parts, if subjected to cold water, after being heated by the friction of a cord made to circulate about

it by two persons alternately pulling in opposite directions. I was subsequently enabled to employ this process, in dividing large vessels, of four or five inches in diameter, and likewise to render it in every case more easy, and certain, by means of a piece of a plank forked like a boot-jack—as represented in the preceding figure; and also having a kerf, cut by a saw, parallel to, and nearly equi-distant from, the principal surfaces of the plank, and at right angles to the incisions, productive of the fork.



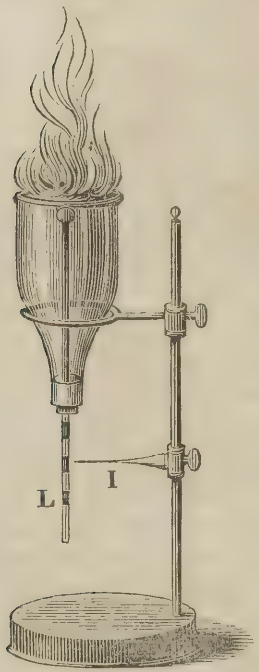
By means of the fork, the glass is easily held steady by the hand of one operator. By means of the kerf, the string while circulating about the glass is confined to the part, where the separation is desired. As soon as the cord smokes, the glass is plunged in water, or if too large to be easily immersed, the water must be thrown upon it.—This method is always preferable when on immersing the body, the water can reach the inner surface. As plunging is the most effectual method of employing the water, in the case of a tube I usually close the end which is to be immersed.

RATIONALE.

If the friction be continued long enough, the glass though a very bad conductor of heat, becomes heated throughout in the part, about which the friction takes place; of course, it is there expanded; while in this state, being suddenly refrigerated by cold water on the outside only, the stratum of particles immediately affected contracts, while that on the inside not being chilled, undergoes no concomitant change. Hence a separation usually follows.

No. 43.—ON THE PROCESS BY WHICH CALORIC IS COMMUNICATED IN LIQUIDS.

That liquids are almost devoid of power to conduct heat, proved by the inflammation of Ether, over the bulb of an air thermometer, protected only by a thin stratum of water.



The inflammation of ether, upon the surface of water, as represented in the following figure, does not cause any movement in the liquid included in the bore of the thermometer at L, although the bulb is within a quarter of an inch of the flame. Yet the thermometer may be so sensitive, that touching the bulb, while under water with the fingers, may cause a very perceptible indication of increased temperature.

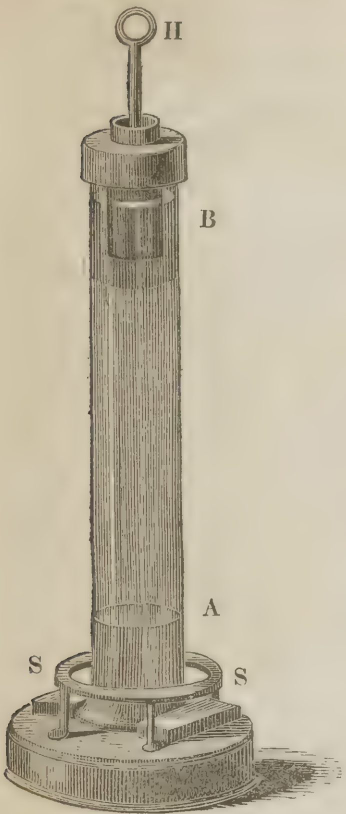
By placing the sliding index I, directly opposite the end of the liquid column in the stem of the thermometer, before the ether is inflamed; it may be accurately discovered whether the heat of the flame causes any movement in the liquid.

No. 44.—COMMUNICATION OF HEAT BY CIRCULATION.

Demonstration that Heat is not sensibly communicated in Liquids except by circulation.

If the upper portion of a vessel, containing a fluid, be heated exclusively, the neighbouring particles of the fluid, being rendered lighter, by expansion, are more indisposed, than before, to descend from their position. But, if the fluid particles, forming the inferior strata in the same vessel, be rendered warmer than those above them, their consequent expansion and diminution of specific gravity, causes them to give place to particles above them, which, not being as warm, are heavier. Hence, heat must be applied principally to the lower part of a vessel, in order to occasion an uniform rise of temperature in the contained fluid.

Experimental Illustration; improved by the Author.



A GLASS jar, about 30 inches in height, is supplied with as much colourless water as will rise in it within a few inches of the brim. By means of a tube descending to the bottom, a small quantity of blue colouring matter is introduced below the colourless water so as to form a stratum as represented at A, in the engraving. A stratum, differently coloured, is formed in the upper part of the vessel, as represented at B. A tin cap, supporting a hollow tin cylinder, closed at bottom, and about an inch less in diameter than the jar, is next placed as it is seen in the drawing, so as that the cylinder may be concentric with the jar, and descend about 3 or 4 inches into the water.

The apparatus being thus prepared, if an iron heater, H, while red hot, be placed within the tin cylinder, the coloured water, about it, soon boils; but the heat penetrates only a very small distance below the tin cylinder, so that the colourless water, and the coloured stratum, at the bottom of the vessel, remain undisturbed, and do not mingle. But if the ring, R, be placed while red hot, upon

the iron stand which surrounds the jar at SS, the liquid soon rises, in beautiful clouds, towards the upper part of the vessel, until it encounters the warmer, and of course lighter, particles, which had been in contact with the tin cylinder. Here its progress upwards is arrested; and, in consequence of the diversity of the colours, a well defined line of separation is soon visible.*

* I used to perform this experiment with an inclined tube, as suggested in Henry's Chemistry. The modification here given, is so far a contrivance of my own, as relates to the use of the heater, tin cap, and iron ring; also using two colours instead of one. On account of the liability of the glass to crack, I found the old method very precarious, when a tube was used large enough to show the phenomena handsomely.

No. 45.—CIRCULATION OF HEAT IN LIQUIDS.

Experimental illustration of the process by which Caloric is distributed in a Fluid until it boils.

On the first application of heat to the bottom of a vessel containing cold water, the particles in contact with the bottom are heated and expanded, and consequently become lighter in proportion to their bulk, than those above them: they rise therefore, giving an opportunity to other particles to be heated, and to rise in their turn. The particles which were first heated, are soon, comparatively, colder than those by which they were displaced, and, descending to their primitive situation, are again made to rise, by additional heat and enlargement of their bulk. Thus the temperatures reversing the situations, and the situations the temperatures, an incessant circulation is supported, so long as any one portion of the fluid is cooler than another: or in other words, till the water boils; previously to which, every particle must have combined with as much caloric, as it can receive, without being converted into steam.

The manner in which caloric is distributed throughout fluids by circulation as above described, is illustrated advantageously by an experiment contrived by Rumford, who first gave to the process the attention which it deserves.

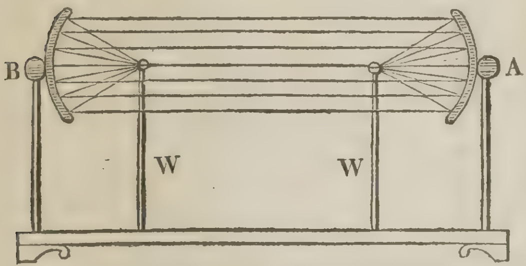
Into a glass nearly full of water, as represented by the foregoing figure, some small pieces of amber are introduced, which are in specific gravity so nearly equal to water, as to be little influenced by gravitation.

The lowermost part of the vessel being subjected to heat while thus prepared, the pieces of amber are seen rising vertically in its axis, and after they reach the surface of the fluid, moving towards the sides where the vessel is colder from the influence of the external air. Having reached the sides of the vessel, they sink to the bottom, whence they are again made to rise as before.—While one set of the fragments of amber, are at the bottom of the fluid, some are at the top, and others at intermediate situations; thus demonstrating the movements, by which, an equalization of temperature is accomplished in fluids.

When the boiling point is almost attained, the particles being

nearly of one temperature, the circulation is retarded. Under these circumstances, the portions of the fluid which are in contact with the heated surface of the boiler, are converted into steam, before they can be succeeded by others; but the steam thus produced, cannot rise far before it is condensed. Hence the vibration and singing, which is at this time observed.

No. 46.—MODEL FOR ILLUSTRATING THE OPERATION OF CONCAVE MIRRORS.—DEVISED BY THE AUTHOR.

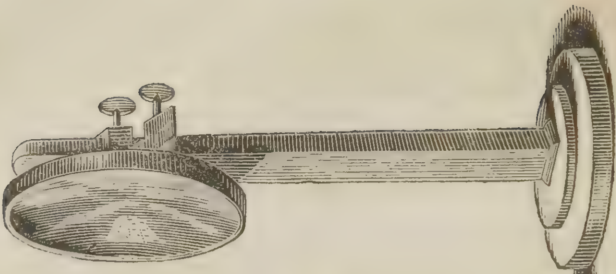


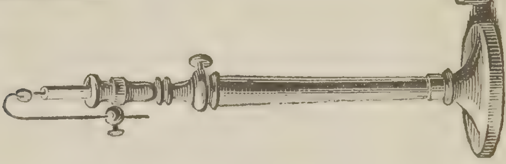
THE object of the model represented by this diagram, is to explain the mode in which two mirrors operate, in collecting the rays of heat in one focus, and in concentrating them in another.

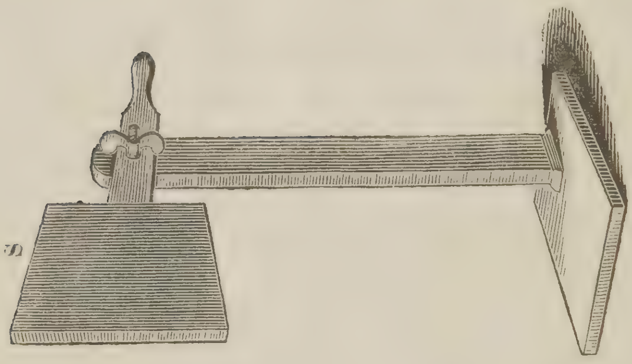
The rays emitted by a heated body in the focus of the mirror A, would pass off in radii lessening their intensity, as the space into which they pass enlarges; or, in other words, as the squares of the distances. But those rays which are arrested by the mirror, are reflected from it in directions parallel to its axis. Being thus corrected, of their divergency, they may be received, without any other loss, than such as arises from mechanical imperfections, by the other mirror; which should be so placed, that the axes of the two mirrors may be coincident; or, in other words, so that a line drawn through their centres, from A to B, may at the same time pass through their foci, represented by the little balls supported by the wires, W W.

The second mirror, B, reflects to its focus, the rays which reach it from the first; for it is the property of a mirror, duly concave, to render parallel the divergent rays received from its focus,—and to cause the parallel rays which it intercepts, to become convergent, so as to meet in its focus.

The strings, in the model, are intended to represent the paths, in which the rays move, whether parallel, or convergent.







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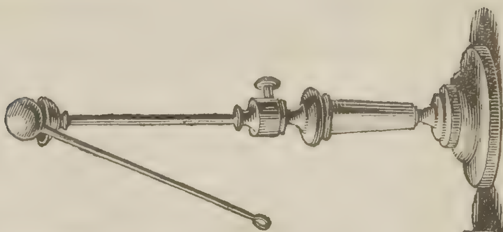
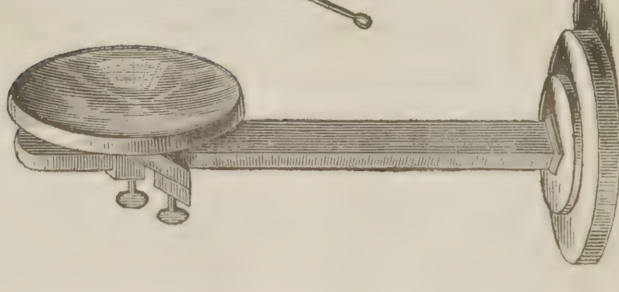




No. 47.—PHOSPHORUS IGNITED AT THE DISTANCE OF TWENTY, OR EVEN AT SIXTY FEET, BY AN INCANDESCENT IRON BALL.

On the opposite side the student will find a representation of the mirrors, which I employ in the ignition of phosphorus, and lighting a candle by an incandescent iron ball at the distance of about twenty feet.

I have produced this result at sixty feet, and it might be always effected at that distance, were it not for the difficulty of adjusting the foci with sufficient accuracy and expedition. I once ascertained that a mercurial thermometer, when at the distance last mentioned, was raised to 110 degrees of Fahrenheit.

Some cotton, soaked in phosphorus, supported by a forceps made out of wire, is placed over the candle wick, in the focus of one of the mirrors, as nearly as possible. A lamp being similarly situated with respect to the other mirror; by receiving the focal image of the latter on any small screen, it will be seen in what way the arrangement must be altered to cause this image to fall upon the phosphorus.

The screen S, placed between the mirrors, is then lowered so as to intercept the rays. The iron, being rendered white hot, is now substituted for the lamp, and the screen being lifted, the phosphorus takes fire, and the candle is lighted.

The mirrors represented by the figure, are 16 inches in diameter, and were turned in the lathe, the cutting tool being attached to one end of an iron bar two feet long, which at the other end turned upon a fixed pivot.

Of course the focal distance, being one half the radius of concavity, is one foot.

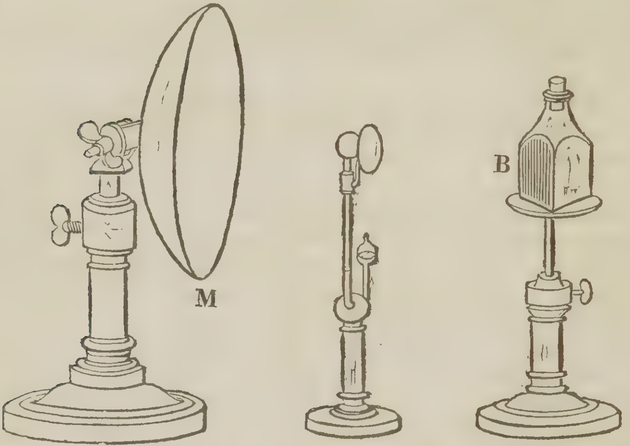
I designed these mirrors, and proposed to have them made out of castings; but pursuant to the advice of Dr. Thomas P. Jones, I resorted to sheet brass, which was rendered the more competent by strengthening the rims with rings of cast brass, about three-fourths of an inch thick each way. For the idea of these rings, and the execution of the mirrors, I am indebted to Mr. Jacob Perkins.

I believe there are none superior, as the face is reflected by them much magnified, but without the slightest distortion.

For the rationale of the operation of the mirrors, I refer to the preceding article.

No. 48.—DIVERSITY OF RADIATING POWER.

Diversity of Radiating Power observable in different Surfaces, illustrated.



At M, in the preceding figure, a parabolic mirror is represented. At B, a square glass bottle, one side of which is covered with tin foil, and another so smoked by means of a lamp, as to be covered with carbon. Between the bottle and mirror, and in the focus of the latter, there is the bulb of a differential thermometer, protected from receiving any rays from the bottle, directly, by a small metallic disk. The bottle being filled with boiling water, it will be found that the temperature in the focus, as indicated by the thermometer, is greatest when the blackened surface is opposite to the mirror; and least, when the tin foil is so situated; the effect of the naked glass being greater than the one, and less than the other.

RATIONALE.

Metals appear to consist of particles so united with each other, or with caloric, as to leave no pores through which radiant caloric can be projected. Hence the only portion of any metallic mass, which can yield up its rays by radiation, is the external stratum.

On the other hand, from its porosity, and probably also from its not retaining caloric within its pores, tenaciously, as an ingredient in its composition, carbon opposes but little obstruction to the passage of that subtile principle, when in the radiant form; and hence its particles may all be, simultaneously, engaged in radiating any excess of this principle, with which a feeble affinity may have caused them to be transiently united—or in receiving the rays emitted by any heated body, to whose emanations they may be exposed.

We may account in like manner for the great radiating power of earthenware and wood.

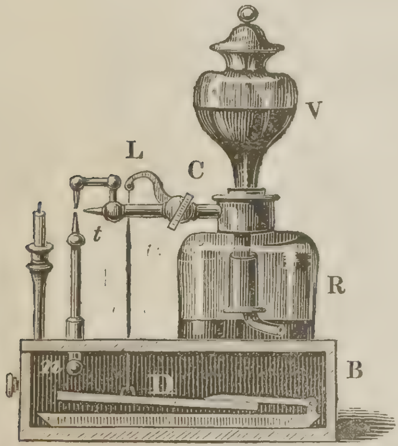
The pre-eminence of metals as reflectors of caloric may be similarly explained.

For the same reason that calorific rays, cannot be projected from the interior of a metal, they cannot enter it when projected against it from without. On the contrary, they are repelled with such force, as to be reflected, without any perceptible diminution of velocity.

It would seem as if the calorific particles, which are condensed between those of the metal, repel any other particles, of their own nature, which may radiate towards the metallic superficies, before any contact actually ensues: otherwise, on account of mechanical imperfection, easily discernible with the aid of a microscope, mirrors would not be as efficacious as they are found to be, in concentrating radiant heat. Their influence, in this respect, seems to result from the excellence of their general contour—and is not proportionably impaired by blemishes.

No. 49.—AN ELECTROPHORUS,

Applied to the ignition of Hydrogen Gas, generated in a self-regulating Reservoir.



In order that the interior of this apparatus may be described, the side of the box B, below the reservoir R, is supposed to be removed.—On the bottom of the box is a square metallic dish, containing a stratum of sealing wax. The metallic plate D, is supported, behind, by a glass rod, cemented to a socket, soldered to an hinge. Upon this hinge, like the lid of a trunk, the plate moves freely, while suspended, from the lever L, by a silken cord. The lever L, is attached to the key of the cock C, so that opening the cock, causes the plate to rise, and touch the knob of the insulated wire *w*. This wire terminates just before the orifice of the tube, *t*, proceeding from the cock, within about one-eighth of an inch of another wire, supported upon that tube.

The glass reservoir R, receives into its open neck, the tapering part of a glass vessel V, which is so proportioned, and fitted by grinding to the neck, as to make, with it, an air tight juncture.

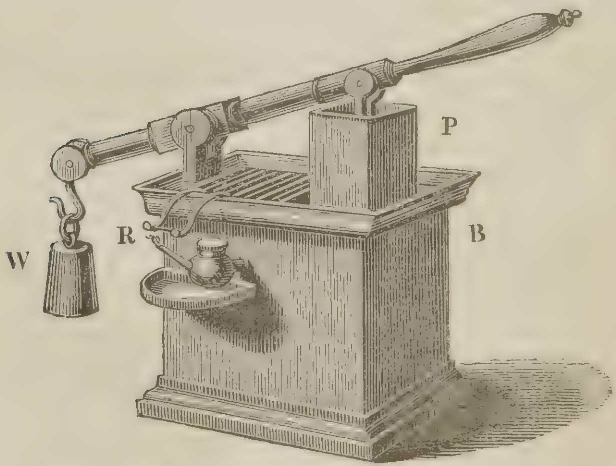
Below this juncture, the vessel V, converges, until it assumes the

form of a tube, reaching nearly to the bottom of the receiver. Around the tube thus formed, or a copper wire, on one side of it, a coil, or cylinder, of zinc is supported; so as to be above the orifice of the tube, constituted as abovementioned.

If the receiver be duly supplied with diluted sulphuric acid, the reaction between this solvent and the zinc, will evolve hydrogen gas. The gas thus evolved, if not allowed to escape, will force the liquid which generates it, through the orifice of the tube proceeding from the vessel V, into the cavity of this vessel, until the quantity of the acid remaining below, be inadequate to reach the zinc; whenever this takes place, the evolution of hydrogen ceases. As soon however, as any portion of the gas is allowed to escape, by opening the cock, an equivalent bulk of acid descends into the receiver, and reacts with the zinc, until by the further generation of hydrogen, as much acid as had descended, be again expelled from the lower, into the upper vessel. At the same moment that, by turning the cock C, a jet of gas is emitted, the plate of the electrophorus being lifted against the knob of the wire, an electrical spark will pass from the other end, of this wire, to that of the wire, supported by the cock, and of course uninsulated by its communication with the operator's hand.—Consequently, the jet of hydrogen will be ignited, and will light a candle, duly subjected to its influence.

For a rationale of the Electrophorus, I refer to the Supplement to my Minutes, Lectures on Electricity, p. 24.

No. 50.—THE GALVANOPHORUS, OR GALVANIC SUBSTITUTE FOR THE ELECTROPHORUS.—DEVISED BY THE AUTHOR.



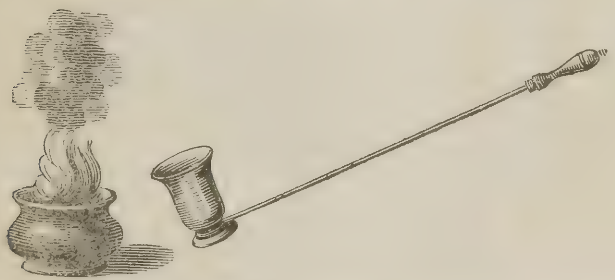
The preceding figure represents an instrument for igniting a lamp, by means of a galvanic discharge, from a calorimotor; for an

explanation of which, I must refer the reader to the Supplement to my Minutes, Lectures on Galvanism, page 43.

The plunger, P, being depressed, by means of the handle attached to it, some acid, contained in the box, B, is displaced, so as to rise among the galvanic plates. By the consequent evolution of the galvanic fluid, a platina wire (fastened between the brass rods forming the poles of the calorimotor, and projecting over the lamp, as seen at R,) is rendered white hot, and a filament of the wick, previously laid upon it, is inflamed.

The weight, W, acts as a counterpoise to the plunger, and keeps it out of the acid, when it is not depressed by the hand.

No. 51.—IGNITION, BY CHEMICAL COMBINATION, ATTENDED BY DECOMPOSITION.



If into a cup a small quantity of alcohol, or of oil of turpentine, with a few grains of chlorate of potash, be introduced, the affusion of a little sulphuric acid will cause the spirit, or oil, to inflame. The oil of turpentine inflames likewise, by the addition of strong nitric acid, or a mixture of nitric and sulphuric acid. The acid may be more safely added by means of a glass, fastened at one end of a rod, as represented in the cut.*

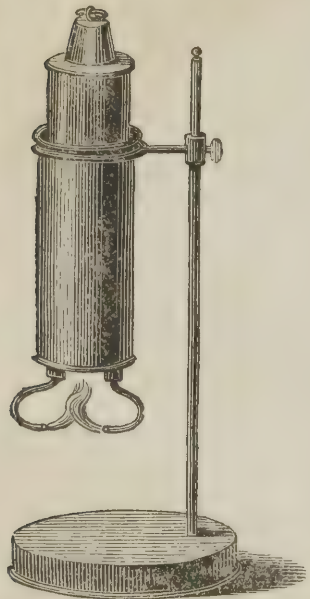
RATIONALE.

It would seem as if certain substances, which always, when uncombined with ponderable matter, exist in the gaseous state, on being converted into solids, or liquids, by a union with other ponderable matter, in some cases retain, in others relinquish, the caloric to which they owed the gaseous state. Hence, if from compounds, in which they retain their caloric, they be taken by the

* Since this figure was drawn, I find a shallow vessel, like a small breakfast-plate, preferable to the cup here represented; which is more contracted at the mouth and deeper than the orignal. The air requisite to support the inflammation, has a more easy access when a plate is used, and the action of the acid on the salt is more generally visible.

superior affinity of substances, whose union with them does not permit the retention of this repulsive principle, its evolution ensues so rapidly, as to produce active ignition. The explosion of gunpowder is an analogous phenomenon.

No. 52.—A NEW MODIFICATION OF THE BLOWPIPE BY ALCOHOL.—BY THE AUTHOR.



This figure represents an improved blowpipe, by alcohol, of which an engraving and description will be found in the Appendix accompanying the Supplement to my Minutes. I will here quote the description there given.

"In the ordinary construction of the blowpipe by alcohol, the inflammation is kept up, by passing a jet of alcoholic steam through the flame of a lamp, supported, as is usual, by a wick. The inflammation, of the jet, cannot be sustained without the heat of the lamp flame, since the combustion does not proceed with sufficient rapidity, to prevent the inflamed portion, from being carried too far from the orifice of the pipe; and being so much cooled by an admixture of air, as to be extinguished. By using two jets of vapour, in opposition to each other, I find the inflammation may be sustained without a lamp. If one part of oil of turpentine, with seven of alcohol, be used, the flame becomes very luminous.

"In order to equalize and regulate the efflux, I have contrived a boiler, like a gazometer. It consists of two concentric cylinders, open at top, leaving an interstice of about one quarter of an inch between them; and a third cylinder, open at bottom, which slides up and down in the interstice. The interstice being filled with boiling water, and alcohol introduced into the innermost cylinder, it soon boils and escapes by the pipes. These pass through stuffing boxes in the bottom of the cylinder. Hence their orifices, and of course the flame, may be made to approach nearer to, or recede further from, the boiler."

No. 53.—LAMP WITHOUT FLAME.

About the wick of a spirit lamp, a fine wire of platina is coiled, so as to leave a spiral interstice between the spiral formed by the wire; a few turns of which should rise above the wick.

If this lamp be lighted; on blowing out the flame, the wire will be found to remain ignited to redness, as it retains sufficient heat to support the combustion of the alcoholic vapour, although the temperature be inadequate to constitute, or produce inflammation.

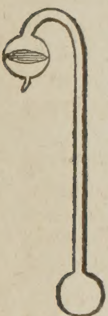
Instead of blowing out the flame, it is better to put an extinguisher over it, for as short a time as will cause the flame to disappear. For this purpose, a small phial, or test tube, is preferable to the metallic cap usually employed.

RATIONALE.

The metallic coil appears to serve as a reservoir for the caloric, and gives to the combustion a stability, of which it would otherwise be deficient.

There is some analogy, between the operation of the wire, in acting as a reservoir of heat in this chemical process, and that of a fly wheel, as a reservoir of momentum, in equalizing the motion of machinery.

No. 54.—WOLLASTON'S CRYROPHORUS.



The adjoining figure represents the Cryrophorus, or frost bearer; an instrument, invented by the celebrated Wollaston, in which congelation is produced in one cavity, by the rapid condensation of vapour in another.

In form, this instrument obviously differs but little from the palm glass represented page 36, No. 38. It is supplied by the same process, with a small portion of water, instead of alcohol; so that there is nothing included in it, unless water, either liquid, or in vapour.

The Cryrophorus being thus made, if all the water be allowed to run into the bulb near the bent part of the tube, and the other bulb be immersed in a freezing mixture, the water will be frozen in a few minutes.

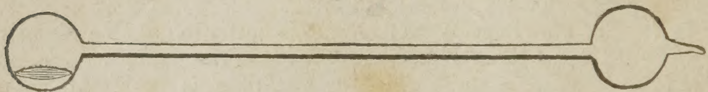
RATIONALE.

So long as no condensation is effected, of the thin aqueous vapour, which occupies the cavity of the instrument, that vapour prevents, by its repulsion, the production of more vapour: but when, by means of cold, the vapour is condensed in one bulb, its extrica-

tion in the other, containing the water, being unimpeded, proceeds rapidly. Meanwhile the water becomes colder, and finally freezes, from losing the caloric which the vaporization requires.

According to Wollaston, one grain of water, converted into aqueous vapour, holds as much caloric as would, by its abstraction, reduce thirty-two grains from 60° F. to the freezing point; and the caloric requisite to vaporize four grains more, if abstracted from the residual twenty-seven grains, would convert them into ice.

No. 55.—LARGE CRYROPHORUS.



The above figure represents a very large Cryrophorus, which I had made at a Glasshouse; and by means of which I have successfully repeated Wollaston's experiment.

This instrument is about four feet long; and its bulbs are about five inches in diameter.